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The Biologic and Economic Assessment of Aldicarb

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THE BIOLOGIC AND ECONOMIC ASSESSMENT OF ALDICARB

Report of the Aldicarb Assessment Team

Submitted to the
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In Cooperation with
State Agricultural Experiment Stations,
Cooperative Extension System,
and Other State Agencies

Preface

This report is a joint project of the U.S. Department of Agriculture and the State Land-Grant Universities. The report was prepared in an effort to provide sound current information on the benefits and risks associated with the use of aldicarb. The report is a scientific presentation to be used in connection with other data by the U.S. Environmental Protection Agency in the special review of aldicarb, which was announced in the Federal Register on 19 June 1988 (pages 24600-24641).

Sincere appreciation is extended to the Assessment Team Members who gave so generously of their time and to others who assisted by contributing data and other information for the development of this report.

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This group has the unreserved thanks of the entire Aldicarb Assessment Team.

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Executive Summary

Aldicarb is an acutely toxic carbamate pesticide causing reversible cholinesterase inhibition. Aldicarb is a granular chemical that is applied to the soil and incorporated. The active ingredient is activated by soil moisture, absorbed by plant roots, and transmitted to foliar portions of the plant controlling various target insects, mites, and nematodes. Rhone-Poulenc Ag Company is the sole registrant of aldicarb, which was first registered in 1970 for use on cotton. Aldicarb is currently registered for use on cotton, citrus, pecan, sugarbeet, sweetpotato, potato, dry beans, peanut, soybean, tobacco, grain sorghum, ornamentals and sugarcane.

The oral LD_{50} in rats is 0.9 mg/kg. Clinical signs of over-exposure in humans are those typical of cholinesterase inhibition and include: blurred vision, excessive salivation, disorientation, seizure, gastrointestinal disturbances and unconsciousness. Extensive overexposure may result in death. A No Observed Effect (NOEL) level for human clinical signs has been reported to be 0.05 mg/kg, with an estimated NOEL of 0.01 mg/kg for human cholinesterase inhibition.

The U.S. Environmental Protection Agency issued a Notice of Rebuttable Presumption Against Reregistration and continued Registration of Pesticide products containing aldicarb on 11 July 1984. The trigger for this action was a determination that aldicarb met or exceeded risk criteria as detailed in 40 CFR 162.11 (a)(6)(i), which provides that a special review be initiated if it appears that "based on toxicological data, epidemiological studies use history, accident data, monitoring data, or such other evidence as is available to the administrator, the pesticide may pose a substantial question of safety to man or the environment...". Potential risks are associated with consumption of raw agricultural commodities and drinking water contaminated with excessive residues of aldicarb.

A benefits assessment team was formed and a questionnaire was developed to determine the key information for each registered crop/site by state. Requested information included acreage, production, use of aldicarb and alternatives including all associated costs. Responses to these questionnaires were used to prepare this report.

Aldicarb has important commercial use on 12 crops in the United States. It is estimated that 5.2 million acres were treated with 10.2 million pounds active (lb ai) ingredient of aldicarb. The total acreage treated and the pounds active ingredient applied crops are listed in Table 1 for each of the major crops.

<u>Citrus:</u> Citrus is grown commercially in five states: Florida, Louisiana, Texas, Arizona, and California. Aldicarb is used in Florida, Louisiana, and Texas. In these three states, 410,700 acres are treated annually with 2.0 million lb ai of aldicarb. The loss of aldicarb would result in an estimated loss of $76 million.

<u>Pecan:</u> Pecan is grown commercially in 10 states: Texas, Arizona, New Mexico, Oklahoma, Alabama, Louisiana, Mississippi, Florida, South Carolina, and Arkansas. Aldicarb is applied on a total of 40,700 acres using 5,200 lb ai of aldicarb. The total cost of cancellation of aldicarb to the pecan industry is estimated at $2.5 to $3.8 million (approximately 1.7% to 2% of the total crop value).

<u>Sugarbeet:</u> About 14.2% (171,543 acres) of sugarbeet is treated with aldicarb to control infestation by sugarbeet cyst nematode, root maggot, leafhoppers, and aphids. No single pesticide or cultural practice could be substituted for aldicarb to provide control of these pests without some

loss of crop yield and value. The loss of aldicarb in Wyoming would likely halt the production of sugarbeet on 25,000 acres due to damage by the sugarbeet cyst nematode. In areas of Minnesota and North Dakota that have severe problems with sugarbeet root maggot, the loss of aldicarb would reduce crop value by about $900,000 annually as a result of less effective control with alternative insecticides. Total annual benefits are estimated to be $16 million.

Sweetpotato: Sweetpotato is grown in twelve states and planted annually on an estimated 92,600 acres. Aldicarb is used on an estimated 18,000 acres annually for control of nematodes. The loss of aldicarb would have the greatest economic impact in Alabama (-$734,807) and North Carolina (-$73,087). The only effective alternative to aldicarb is soil treatment with 1,3-dichloropropene. It is estimated that 3,158 acres currently treated with aldicarb would not be treated with 1,3-dichloropropene. Without nematode control, the crop would sustain heavy yield and quality losses and may ultimately be abandoned in some areas. The total national annual benefits are estimated to be $800,000.

Potato/Seed: Aldicarb is used on an estimated 357,500 acres of the 1.2 million acres planted in the United States. The estimated value of the crop is $1.6 billion. The loss of aldicarb to control nematodes, insects and diseases would result in an estimated $90.4 million reduction in income. Due to the negative impact on the production of quality seed potato, the impact may be greater than indicated. Production would be abandoned on significant acreage in Florida, Pennsylvania, Alabama, and Colorado if aldicarb is lost.

Dry Beans: Dry beans are harvested on approximately 1.5 million acres in 14 states each year; production is concentrated in the North-Central and Western States. Aldicarb is used in dry bean production for control of nematodes, spider mites, lygus bugs and other insect pests. Dry bean producers would lose and estimated $321,446 if aldicarb were no longer available. Because aldicarb is important in the management of spider mite resistance to foliar acaricides, it is particularly important to bean production in the West.

Cotton: The major use of aldicarb on cotton is as an in-furrow treatment at planting to control thrips, aphids, spider mites, and nematodes and to suppress plant bugs. Sidedress applications, made 2-4 weeks after plants emerge provide extended control of aphids, spidermites, lygus bugs, fleahoppers, and whiteflies. In-furrow application also stimulates early plant growth which contributes to better weed control. In 1988 cotton was planted on a total of 12.2 million acres and approximately 3.1 million (25%) were treated with aldicarb. Cotton treated with aldicarb matures earlier, allowing harvest prior to adverse weather. No single pesticide will fill the niche of aldicarb on cotton. Total annual benefits from aldicarb in U.S. cotton production are estimated to be $89 million.

Peanut: Peanut is grown on about 1.5 million acres annually. It is estimated that 974,400 lb ai of aldicarb is applied to peanut each year for insect and nematode control. The loss of aldicarb would reduce producer income by $13.7 million annually. To maintain peanut stocks at current levels, as well as government production quotas, a grower investment of $9.7 million would be required annually. Assuming supplies of alternative products were available for this transition and that additional land were available to increase production acreage, the cost of using alternatives to aldicarb would be $23.4 million in the first year. Annual costs to growers would change thereafter according to adjustments in production costs and the cost of alternatives.

Soybean: Aldicarb is used primarily as a nematicide on U.S. soybean, but only 0.4 percent (237,000 acres) are treated. Total aldicarb use on soybean is estimated to be 333,300 lb ai annually. Crop rotation coupled with the planting of nematode resistant cultivars appear to be an effective alternative to applications of aldicarb. However, the absence of rotational crops that are

as profitable to grow as soybean, particularly in the southeastern states, may limit the economic feasibility of this practice. Furthermore, the absence of cultivar resistance to the northern root-knot (*Meloidogne hapla*), ring (*Macrophtbonia* spp.), sting (*Belonolaimus* spp.), and several other nematode species places serious limits on the use of this alternative to aldicarb.

Tobacco: North Carolina and Virginia are the only states where aldicarb is used for pest control in tobacco. About 7% (18,804 acres) of the crop in both states is treated annually with 40,161 lb ai of aldicarb. The impact of suspending the use of aldicarb on flue-cured tobacco would result in an estimated loss to U.S. producers of about $3.8 million. In addition, the loss of aldicarb may increase the potential for tobacco aphid resistance since the only chemical alternative is acephate.

Ornamental Crops: Production of ornamental plants is one of the fastest growing agricultural industries in the United States, 10% since 1982. In 1987 it accounted for 11% of all farm cash crop receipts. An estimated 41.9 million acres are treated with 162.8 million pounds of aldicarb to control insects, spider mites, and nematodes. The economic impact of losing aldicarb would be insignificant if the cost of the chemical replacement was the only consideration. However, there would be considerable increases in: cost of equipment and labor, number of pesticide applications and number of pesticides used as alternatives, the number of workers exposed to pesticides, and environmental contamination. No single insecticide can replace aldicarb in the ornamental industry and economic comparisons do not adequately describe the impact of the loss.

Table 1. Aldicarb usage in the United States		
Crop	Acres Treated (x 1000)	Total chemical usage (lb ai x 1000)
Citrus	410.7	2,033.4
Pecan	40.7	5.2
Sugarbeet	171.5	704.1
Sweetpotato	18.0	49.0
Potato/seed	357.5	1,072.5
Dry beans	31.0	40.8
Cotton	3,100.0	4,650.0
Peanut	653.7	974.4
Soybean	237.5	333.3
Tobacco	18.8	40.2
Grain sorghum	97.6	97.6
Ornamental plants	41.9	162.8
Total	5,178.9	10,163.3

Table 2. Annual economic benefits derived from the use of aldicarb

Crop	Total benefits	Yield loss	Quality reduction	Pest control costs	Other production costs	Total benefits per treated acre
	thousand $					($/acre)
Citrus	76,121	83,856		-7,737		128.84
Pecan	2,470					60.67
Potato	90,385	91,870		-1,486		270.21
Sweetpotato	800					44.53
Dry Beans	321	289		32		10.35
Sugarbeet	16,049					93.56
Cotton	89,013	70,815	7,409	5,121	5,667	25.15
Peanut	13,733	16,692[1]		-2,959		21.01
Soybean	-5,420[2]	-5 ,582		162		
Tobacco	3,785					201.33
Total	292,697					

[1]Includes both yield and quality losses.
[2]Losses due to use on soybeans not included in the benefit total.

Introduction

The aldicarb benefits assessment team was organized by the National Agricultural Pesticide Impact Assessment Program (NAPIAP), U.S. Department of Agriculture in June l88 to develop an objective study of the uses and benefits of aldicarb to U.S. agriculture. The assessment team was asked to examine the economic and social impacts that may result if the registration of aldicarb were canceled. The preliminary determination to cancel was announced by EPA in the Federal Register on June 19 1988 (pages 24600-24641).

Aldicarb is the common name for 2-Methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime, which was discovered by Union Carbide Corporation in 1962. It was registered under the trade name of Temik in 1967. It was first registered for use on cotton in 1970. Today it is labeled for use on 13 crops in the United States, including citrus, pecans, potatoes, sweet potatoes, dry beans, sugar beets, cotton, peanuts, soybeans, tobacco, sugar cane, grain sorghum and commercial ornamental plants.

Aldicarb is the most effective systemic insecticide-nematicide that has ever been registered for use in the United States. It is most effective against sucking pests such as thrips, aphids, spider mites, whiteflies, lygus bugs, leafhoppers and nematodes. It also provides some control of certain coleopterous and lepidopterous pests. In addition to being a very effective pesticide, it also enhances vigor and (at times) increases yield more than can be attributed to pest control (see the citrus chapter for additional comments).

Aldicarb is sold as a granular formulation and is applied directly into the soil or as a band that is mixed with the soil. It is most effective for insect control when applied in a concentrated band in the seed furrow or injected into the root zone. Most band applications are made to control nematodes and are mixed with the soil. These methods of application greatly reduce hazards to applicators, field workers, wildlife and the environment.

Characterization of Aldicarb

Physical and Chemical Properties: The active ingredient in aldicarb is 2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime. Technical aldicarb is a white crystalline solid with a low vapor pressure and high water solubility. The molecule is a member of the chemical family of pesticides known as oxime carbamates (Union Carbide and Rhone Poulenc Literature).

Mode of Action: Aldicarb is an acutely toxic pesticide causing reversible cholinesterase inhibition. The LD_{50} in rats is 0. mg/kg. A wide range of clinical symptoms in humans result from cholinesterase inhibition, including: blurred vision, excessive salivation, gastrointestinal disturbance, disorientation, and seizures. Extended cholinesterase inhibition may result in death.

Formulations Marketed: Aldicarb is marketed as granular products containing 10% or 15% active ingredient. The 15% granular formulation is registered for control of insect, spider mite and nematode pests of row crops, citrus and pecans. The 10% granular formulation is registered to control the same pests on commercially grown ornamentals. Although the technical compound is acutely toxic, its formulation into granular products significantly reduces the hazard of its use.

Application: Aldicarb is a restricted use pesticide, and as such can only be legally applied under the supervision of a certified applicator. All recommended uses require that the granules be placed

into or incorporated with soil thus further reducing the hazard of its use to applicator, birds and wildlife. No mixing or direct handling of the granules is required in the application process.

Methodology of the Benefits Assessment

The assessment team was divided into subteams according to the crop specialties of members. Each subteam developed a questionnaire to obtain the information needed for the assessment from State Pesticide Impact Assessment Liaison Coordinators and other knowledgeable scientists.

Overall quality of the data was very good. The data for acreage and yield was compared to crop reporting service reports and were adjusted when necessary. If ranges were reported, the mid-point of the range was used in the analysis.

The methodology for the economic analysis centered on the changes likely to occur if aldicarb were no longer available for use. These can include changes in pest control costs, yield, quality and other related production costs such as weed control. No consideration was given to possible crop market price adjustments or regional shifts in production resulting from changes in comparative advantage. The annual benefits were determined by summing the dollar value of all relevant changes.

Annual benefits were derived as:

$$B=\sum_{i=1}^{m}\sum_{j=1}^{m}[(P_{ij}Y_{ij}^{0}-P_{ij}Y_{ij}^{1})+(C_{ij}^{1}-C_{ij}^{0})+(O_{ij}^{1}-O_{ij}^{0})]$$

where:

- B = annual benefits attributable to aldicarb use,
- P = average crop price (1985-87),
- Y^0 = average yield (1983-87) (reflecting quantity and quality) when crop treated with aldicarb,
- Y^1 = expected yield using chemical alternatives to aldicarb,
- C^1 = pest control cost using likely alternative control,
- C^0 = pest control cost using aldicarb,
- O^1 = other related production costs using chemical alternatives to aldicarb,
- O^0 = other production costs related with aldicarb use,
- j = number of states, and
- i = number of crops.

Crop prices were 3-year averages (1985-87) as published in *Agricultural Statistics* (1988).

The data for the calculation of the annual benefits was obtained from questionnaire responses. Data on aldicarb treated acreage, yield losses, quality losses, and likely alternative controls were compiled from the questionnaire. In general, chemical prices were standardized across states and crops through the use of a national price list (Mason, 1989).

Fruit and Nut Crops

Aldicarb Use on Citrus

Joseph L. Knapp

Citrus is grown in California, Arizona, Texas, Louisiana, and Florida. Aldicarb is not of sufficient interest or value to California citrus production to support its continued registration in that state (Morse, 1989). Arizona did not respond to written nor phone inquiries regarding the use of aldicarb on citrus in that state.

Aldicarb is a restricted use pesticide for citrus registered for control of certain insects, mites, and nematodes on oranges, grapefruit, lemons, and limes (Table 3). Commercial acreage, production, and on-tree value of citrus in Florida, Texas, and Louisiana are provided in Table 4.

A tolerance of 0.3 ppm for the combined residues of aldicarb and its major metabolites in or on the raw agricultural commodity, oranges was published in the Federal Register on 21 March 1977 with initial crop production in 1978. This was followed by a similar tolerance on grapefruits, lemons, and limes published on 20 November 1981.

Chemical Usage

Aldicarb is registered at 5.0 pounds active ingredient (lb ai) per acre for the control of citrus nematodes, citrus rust mites, aphids, and Texas citrus mites on Florida citrus. It provides excellent control of all target pests except for Texas citrus mites. However, the majority of product is utilized for the grower to achieve increased yield, brighter and smoother textured peel, and a more vigorous tree. These advantages generally occur following aldicarb use even in the absence of significant populations of any of the target pests. Such advantages appear to plateau after three to four years of consecutive use. Additional research is needed on the plant growth regulator type activity to better understand its mode of action and how best to utilize the product for this benefit. After the plateau is it reached, it is not known how to best maintain this level of production compatible with target pest control, i.e., one-half rate every year, full rate every other year, etc. This effect on tree vigor as it relates to freeze tolerance and to fertilizer and water utilization also needs to be investigated.

Florida Use History

Aldicarb was registered and research data supported efficacy for the control of nematodes, citrus rust mites, spider mites, and aphid pests of citrus. The University of Florida recommended its use for control of citrus nematodes based on environmental concerns and applicator safety (Knapp et al. 1989). No post planting alternative was registered in 1978 for this site/target pest. If aldicarb was used for nematode control, no foliar miticide would be required in the following regular foliar spray program.

Aldicarb residues were detected from ground water samples and a significant residue level was found in a drinking water well immediately adjacent to a citrus grove which was treated with aldicarb in the spring of 1982. These findings were made public in the *Orlando Sentinel* on 1 August 1982. On 27 December 1982, the Florida Commissioner of Agriculture temporarily

suspended the use of aldicarb in Florida except for nursery plants grown in containers through Emergency Rule No. 5E-ER-83-I.

A Temik task force comprised of representatives of five state agencies was formed and on 18 January 1983, the Florida Commissioner of Agriculture filed emergency rule SE-ER-83-2 based on their recommendations. This rule provided: 1) all uses of aldicarb be classified as restricted use, 2) the implementation of a reporting procedure whereby advance notice would be given to the Department of Agriculture of all proposed use of aldicarb except in potted or containerized plants, and 3) the summary of this emergency rule also temporarily suspended all uses of the pesticide aldicarb except for nursery use in containerized plants. This rule was effective through the 1983 calendar year. On 1 January 1984, the use of aldicarb was allowed under the following rule: "Restricted Use Pesticides - Reporting of intended application of aldicarb". These new regulations were based on studies summarized in two publications; "Aldicarb Research - Task Force Report" University of Florida, IFAS, September 1983 and "Summary of Florida Aldicarb Studies" Pesticide Review Section, Florida Department of Environmental Regulation, Tallahassee, Florida, August 1984.

Concurrent with the lifting of the use ban on aldicarb, the Union Carbide Corporation (UC) added use restrictions to the aldicarb label in Florida only, changed the granule base to gypsum, and initiated its stewardship program. Through this program, UC provided elaborate training in the safe and legal use of aldicarb to its distributors, dealers, applicators, and customers. All application sites were viewed by UC employees, all wells posted, set backs from wells marked, and treated groves posted. This program is still in effect.

These basic use restrictions have been effective in preventing drinking water contamination with dangerous levels of aldicarb and its metabolites, applicator overexposure, and kills of non-target organisms.

Use on Non-Bearing Trees

Prior to a series of damaging freezes in the early and mid 1980s, Florida citrus was a mature industry of approximately 850,000 acres. In 1985, the production area had been reduced to 503,000 acres. Florida's total citrus acreage as of January 1988 was 697,929 acres, an increase of 73,437 acres. The current 12 percent increase is a result of extensive new plantings in the southern areas, replanting of frozen-out blocks, and resetting and interplanting in existing groves. Acreage of non-bearing trees is currently 176,127 acres with a continued planting schedule to achieve the prefreeze acreage, 800,000 to 850,000 (Fla. Ag. Stat., 1988).

Aldicarb is currently applied to non-bearing citrus at the rate of 0.3 oz ai per tree (not to exceed 5 lb ai/acre) by specially designed applicators. Various rate, timing, and placement regime have been on going by the University of Florida for 3 years. There has been an absence of target pests at all sites. Unpublished data to date show no measurable growth enhancement; i.e., trunk diameter or tree height of aldicarb treated compared to untreated controls at any of the sites. At one site, after 3 years, a trend of increased tree growth may be developing. At another site aldicarb applied to grapefruit at planting resulted in moderate to severe phytotoxicity based on product placement. Commercial harvest after 2 years showed no difference in yield between treated and untreated. However, aldicarb treated trees produced fruit with noticeably brighter and smoother textured peel. All trials are continuing.

Use on Bearing Trees

University of Florida trials conducted in 1980-82 on 'Valencia' oranges showed a 39 percent yield increase or a difference in net returns of $517.81 per acre, over a untreated block. There was no difference in citrus nematode or citrus rust mite populations in either block (Knapp et al., 1982).

Other tests (Timmer and Childers, 1978) comparing yield between aldicarb and fenamiphos are summarized in Table 5. There was a significant yield increase in the aldicarb treated trees compared to those treated with fenamiphos. There were no differences in internal fruit qualities between treatments.

Since 1983, the use of aldicarb in Florida citrus has steadily increased. In 1988, intent to apply aldicarb permits were filed for its use on 397,619 acres or 58 percent of the total registered variety acreage (Table 6). A single application of 5 lb ai/acre is applied by specially designed application equipment between January and April 30 of each year. Aldicarb use during this period precludes the use of a foliar miticide spray generally applied with foliar nutritiants to the fully expanded spring leaf-flush (April-May).

The evaluation of aldicarb for use on Florida citrus has consistently resulted in greater yields in the aldicarb vs. alternative chemicals vs. non-treated control blocks even in the absence of target pest populations. In addition to yield increases, aldicarb has also demonstrated higher Brix (total soluble solids), increased fruit size, and improved fruit color (Wheaton et al., 1985). In the previous study, leaf P and Ca were increased; however, no differences were detected in trunk growth, flowering or vegetative growth characteristics due to aldicarb. Trees receiving aldicarb in this test suffered less freeze damage than control trees in a single site during the January 1985 freeze.

Chemical Alternatives for Pest Management

Information about the recommended chemical alternatives to aldicarb is summarized in Table 7.

Fenamiphos (Nemacur 3E and 15G) is currently registered and recommended for citrus and burrowing nematode control. This product has no demonstrated insecticidal or miticidal activity. Tree vigor and yield enhancements similar to those described for aldicarb in the absence of pest populations have not been demonstrated. The use of fenamiphos has been limited to areas where aldicarb is not used; i.e., adjacent to wells in the set-back zone where it is illegal to apply aldicarb, to hybrid citrus varieties where Temik 15G is not registered, where burrowing nematodes are a known problem and by growers with nematode problems and not wanting to use Temik 15G.

The foliar miticides, ethion, dicofol, and fenbutatin-oxide are currently recommended. The University of Florida recommends that these products not be used more than once per season. The use of aldicarb precludes the use of these products in the post-bloom period spray thereby allowing their use at other times in the growing season. The economic advantage of the use of aldicarb on Florida citrus cannot be totally accounted for on the basis of pest (either known or unknown) control. Therefore, it is logical to assume the use of any combination of available alternatives will result in reduced grower revenues. In addition, with re-registration, special pesticide reviews, and resistance, the citrus grower is subject to the loss of any or all products at any time.

Texas: A freeze in 1983 had a tremendous impact on Texas citrus acreage and production resulting in a loss of 35,000 acres of bearing trees. Currently there are 28,000 acres of bearing trees (grapefruit and oranges) and 5,000 acres of non-bearing trees. Aldicarb is applied to approximately 50 percent of the bearing acres once a year at the rate of 5 lb ai/acre. Its primary purpose is mite control (both citrus rust and spider mite), followed by citrus nematode control, insect control, and a growth regulator effect that is percieved by many growers. Contributors indicate an average of 10 to 15 percent yield reduction could be expected even with the best known combination of alternative miticides and nematicides if aldicarb were lost. Target pests, alternatives, and costs are summarized in Table 8.

Louisiana: There is approximately 1,000 acres of citrus grown in Louisiana of which approximately 5 to 10 percent is treated with aldicarb. The use patterns include a split application (spring & fall) 5 to 10 lb ai/acre for citrus red mite control or a single 10 lb ai/acre in the spring for citrus nematode and citrus red mite control. Target pests, alternatives and costs are summarized in Table 9.

Economic Impacts Caused by Aldicarb Cancellation

The economic analysis of aldicarb use in citrus production focuses on the sum of the yield losses and changes in pest control costs which can reasonably be expected if alternative controls must be substituted for aldicarb. These benefits are presented in Table 10. The total annual benefits from aldicarb use on citrus were estimated to exceed $76 million. The majority of the benefits accrue from the savings of yield loss in Florida orange production. Yield losses ranged from 12.5 percent to 15 percent per acre. The yield losses in general are of a magnitude considerably larger than the changes in control costs. In many cases, the cost of the alternative controls is less than that of aldicarb. Hence, the changes in control costs appear as negative numbers in Table 10.

The benefits per acre of bearing trees were calculated for the relevant production regions and commodities. The highest per acre benefits were observed for Florida lemons and the lowest were for Louisiana oranges. In total the benefits estimated as almost $129 per acre. When the annual economic benefits were compared to the value of production of all citrus production regions under consideration, the economic benefits of aldicarb use account for approximately 8 percent of the value of production.

Summary

Aldicarb is used by citrus producers primarily in three states. It was estimated that about 410,000 acres in Florida, Texas, and Louisiana are treated annually with an approximate total aldicarb use of 2 million pounds per year. Florida has the highest proportion of citrus acreage that was treated with aldicarb (58 percent) and Louisiana has the smallest (7.5 percent).

In specific regions of citrus production, the use of aldicarb generates significant per acre benefits. While less expensive alternative controls may be available, important yield losses could be expected in several production regions. Particularly in Florida and Texas, the cancellation of aldicarb would translate into a substantial loss for citrus producers. The estimates of per acre benefits in these two states ranged from $121.19 to $423.41 per acre. Total annual benefits for all citrus regions considered were estimated at slightly over $76.0 million.

Table 3. Registration summary for aldicarb		
Pest controlled	Application rate (lb/acre at 18-25 ft row spacing)	Recommended application
Citrus Nematode	67 (Except Florida)	Apply just prior to or during the spring flush growth in band along the dripline on both sides of tree row. Spread granules uniformly & immediately work into the soil. (preferred method); OR shank granules 2 to 3 inches deep using 4 to 6 shanks on 12 inch centers. The width of each and should equal one forth the tree row spacing.
	33-66 (Texas only)	
Aphids Mites: Citrus Red Citrus Rust Texas citrus Whiteflies	33-66 (except Florida)	Apply as above, or apply in irrigation furrows using two shanks per furrow.
Aphids Mites: Citrus rust Texas citrus	33 (Florida only)	Apply as above between January 1 and April 30 only. See other ENVIRONMENTAL LIMITATIONS.
Citrus Nematode	33 (Florida only)	Apply as above between January 1 and April 30.
Source: Florida Citrus Spray Guide, University of Florida, IFAS, Jan. 1989.		

TABLE 4. Citrus production in the United States					
STATE	ACREAGE			PRODUCTION X 1000 Boxes	ON TREE VALUE X $1000
	VARIETY	BEARING	NON-BEARING		
Florida	Oranges Grapefruit Lemon Limes	448,132 105,962 1,175 6,551	110,449 13,644 42 528	142,954 49,802 620 1,415	686,179 247,018 1,594 12,126
Totals		561,820	124,663	194,791	946,917
Texas	Oranges Grapefruit	28,000	5,000	875 1,925	6,384 13,511
Totals		28,000	5,000	2,800	19,895
Louisiana	Oranges	1,000	500	100	250
Total		1,000	500	100	250
Sources: Florida - Citrus Summary, Fl. Ag. Stat. Ser. Orlando, Fl, 1987-88.					

Table 5. Performance evaluation of aldicarb and Nemacur 15G on Hamlin Oranges in Florida, 1988.			
Chemical	Application rate (kg/tree)	Yield (No. tree boxes)	Average fruit weight (G)
Temik 15G	326 a	7.96 a	131.4 a
Nemacur 15G	291 bc	6.75 b	126.4 ab
Control	269 c	6.58 b	120.2 b

Source: Timmer, L.W. and C.C. Childers, 1987. Effect of aldicarb treatments on populations of the citrus nematode; *Tylenchulus semipenetrans*. Unpublished data.

Table 6. Aldicarb applications to citrus, 1988			
State	Chemical applied (lb 15G)	Acres treated	% acres treated
Florida	13,121,427	397,619	58
Texas	429,000	13,000	40-45
Louisiana	1,650 - 6,700	50-100	5-10

Source: Florida - Florida Department of Agriculture and Consumer Services.

Table 7. Usage of aldicarb and its alternatives in Florida

Chemical	Formulation	Application rate (lb ai/acre)	Chemical cost ($)	Application cost ($)	Total cost ($)	No. applications/target pest
Aldicarb	5G	5	106.00	12.00	118.00	1 Citrus Nematode Citrus Rust Mite
Fenamiphos	15G	10	180.00	12.00	192.00	1 Citrus Nematode Burrowing Nematode
Fenamiphos	3E	10	175.00	12.00	187.00	1 Citrus Nematode Burrowing Nematode
Ethion	4EC	.35/100 gals.	16.75	32.28	49.03	1 Citrus Rust Mite Spider Mite Scales
Dicofol	4MF	.4/100 gals.	24.00	32.28	56.28	1 Citrus Rust Mite Spider Mite
Fenbutatin Oxide	50WP	1.5 LB	49.62	32.28	81.90	1 Citrus Rust Mite Spider Mite
Fenbutatin Ooxide	4L	.125-.2/ 100 gals.	26.25	32.28	58.53	1 Citrus Rust Mite Spider Mite

Source: J.L. Knapp

Table 8. Usage of aldicarb and its alternatives in Texas

Chemical	Formulation	Application rate (lb ai/acre)	Chemical cost ($)	Application cost ($)	Total cost ($)	No. applications/target pest
Aldicarb	15G	5	110.00	3.50	113.00	1 Citrus Nematode Citrus Rust Mite
Fenamiphos	15G	20	400.00	3.50	403.50	1 Citrus Nematode
Fenamiphos	3E	20	350.00	--	350.00+	1 Citrus Nematode
Ethion	4EC	3	29.50	20.50	50.00	3-4 Citrus Rust Mite
Dicofol	4MF	3	22.50	27.75	50.00	3-4 Citrus Rust Mite Citrus Red Mite Texas Citrus Mite
Fenbutatin Oxide	4L	0.75	23.75	26.25	50.00	3-4 Citrus Red Mite Citrus Rust Mite Texas Citrus Mite
Oxamyl	2E	1	25.00	25.00	50.00	1 Citrus Nematode

Source: See list of contributors at end of section.

Table 9. Usage of aldicarb and its alternatives in Louisiana

Chemical	Formulation	Application rate (lb ai/acre)	Chemical cost ($)	Application cost ($)	Total cost ($)	Number of applications	Target pests
Aldicarb	15G	67 LB	40.00	5.00	45.00	2	Citrus Nematode Citrus Red Mite
Fenamiphos	15G	120 LB	245.00	5.00	250.00	1	Citrus Nematode
Ethion	2EC	.125/100 gals.	5.00	3.50	8.50	1	Citrus Red Mite
Dicofol	4MF	1.3/100 gals.	2.50	2.00	4.50	2	Citrus Red Mite
Fenbutatin Oxide	50WP	1.0 LB	12.50	2.50	15.00	3-4	Citrus Red Mite

Source: See list of contributors at end of section.

Table 10. Economic benefits of aldicarb in citrus, 1990

	Florida oranges	Florida grapefruit	Florida lemons	Florida limes	Texas oranges	Texas grapefruit	Louisiana citrus
Acres: bearing	448,132	105,962	1,175	6,551	28,000[1]		1000
Non-bearing	110,449	23,644	42	528	5,000[1]		500
% ALDICARB Treated	58	58	58	58	50[1]		7.5
% Yield Loss	15	15	15	15	12.5	12.5	15
Avg Price/box	$5.348	$3.48	$7.50	$7.94	$5.84	$4.69	$25
Value of Yield Loss($)	66,513,065	15,078,050	404,550	975,730	319,375	564,265	2,812
Change In Production Costs ($)	-9,460,090	-2,236,860	92,959	518,275		3,342,500	6,705
Total Benefit ($)	57,052,975	12,841,190	497,509	1,494,005		4,226,140	9,517
Benefit Per Bearing Acre(/A)	127.31	121.19	423.41	228.06		150.93	9.52

Total Annual Benefit for Citrus: $76,121,330.

Total Annual Benefits Per Bearing Acre: $128.84

Total Annual Benefits/Total Value of Production: .079

[1]Combined orange and grapefruit acreage for Texas

Aldicarb Use on Pecan

James D. Dutcher

Pecan is produced in the southern United States, Kansas, Oklahoma, New Mexico, Arizona, California, Mexico, Canada (Table 11). Season-long protection of the foliage of pecan, *Carya illinoinensis* (Wangh.) K. Koch, from attack by the pecan aphid, leafminer and mite complexes has been achieved by a single soil incorporated application of the systemic insecticide aldicarb on young trees (Polles and Canerday, 1972) and mature trees (Gentry et al., 1976). Aldicarb also reduces plant parasitic nematodes in the pecan orchard soil and improves nut quality (Powell and Hendrix, 1979; Hendrix and Powell, 1979). Good efficacy ratings were reported against the yellow pecan aphids (Tedders and Osburn, 1970; Gentry et al., 1976) and foliage retention is improved leading to higher production of flowers the following spring (Dutcher and Harrison, 1984; Dutcher et al., 1984).

Registration Summary and Application Methods

The 15G formulation of aldicarb is currently used on pecan. The application rate ranges from 1.25 to 10 pounds active ingredient (lb ai) per acre for the mid-May application when one application per year is made. If a second application is made, the maximum rate is 3.0 lb ai/acre.

Aldicarb is usually applied in mid-May. A single application is often made at a maximum rate of 3.0 lb ai/acre in mid-July and early-season aphids are controlled with foliar sprays or beneficial insect enhancement. Drip irrigation of pecan has facilitated aldicarb application resulting in increased efficacy at lower application rates (Alverson 1984 and 1985; Alverson and Aitken, 1985; Alverson and Hornby, 1987; Dutcher et al., 1984; Dutcher and Harrison, 1984; Dutcher and Worley, 1983; Gorsuch and Aitken, 1985). Split applications are registered in several states (Table 16) but experts indicate that this technique is seldom used.

Pest Infestation

The pecan aphid is the primary target pest controlled with aldicarb. The other primary pests are: aphids (Blackmargined aphid, *Monellia caryella* [Fitch]; yellow pecan aphid, *Monelliopsis pecanis* Bissell; black pecan aphid, *Melanocallis caryaefoliae* [Davis]), leafminers, walnut caterpillar (*Datana integerrima* [Grote and Robinson], *Stigmella juglandifoliella* [Clemens], *Coptodisca lucifluella* Clemens [Heliozelidae], *Phyllonorycter caryaealbella* [Chambers], *Cameraria caryaefoliella* [Clemens]), mites (two-spotted spider mite), *Tetranychus urticae* Koch; pecan leafscorch mite, *Eotetranychus hicoriae* [McGregor]; pecan leafroll mite, *Eriophyes caryae* Keiffer), and nematodes (3 species of root knot nematode).

Pest Management

Current Chemical Usage

The majority of pecan growers use a single application of aldicarb before July 15 at a rate that is dependent on the application method (Table 12). This single mid-season application is the least expensive method for control of late-season aphid populations. Late-season aphid populations cause the most serious damage in the southeastern United States. The rate of application can be as high as 10 lb ai/acre for a single mid-May treatment. Most growers indicated that they used 3 to 5 lb ai/acre for the first nut set application and 3 lb ai/acre for the mid-summer application.

Aldicarb is used on approximately 9.8 percent of the total improved pecan acreage in the United States (Table 13). Oklahoma, California, Kansas, and North Carolina do not use aldicarb in pecan management. No uses were reported on native stands or seedling orchards. Many native stands are closely associated with river systems where aldicarb application is prohibited by label restrictions. Estimates from a survey in 1985 (Padula, 1985) indicated that 64,000 acres of pecan is treated with aldicarb and 300,000 lb of actual insecticide were used on those acres. Our 1988 survey indicates that 40,710 acres were treated with a total of 202,050 lb of actual insecticide. There is no way to calculate a margin of error in this estimate, as it is a collection of opinions by experts in pecan production.

Chemical Alternatives for Pest Management

Table 16 has a rating for each currently registered chemical control commonly used to control aphids and mites on pecan. These are of two types:

Trunk Injection with Dicrotophosis an alternative control for foliar insects with systemic insecticides. Dicrotophos is registered for this use in many southeastern states (Dutcher et al., 1980 and 1985). This method is effective against most foliar insect pests and is marginally effective against pecan leaf scorch mite. It is also a completely closed application system with minimum environmental contamination. Currently its use is limited to urban plantings of pecan. The cost of application and materials is $12 to $20/tree per season.

Foliar Insecticides are also used in conjunction with a scouting program for aphid and mite control. Scouting is not an extra expense as a result of using foliar sprays. The aldicarb control may not last the entire season so that scouting is still required and supplemental foliar sprays may be needed to control aphids and mites when the residual efficacy of aldicarb is reduced. Also, aldicarb does not control any nut pests of pecan and is not effective against fall webworm. Foliar sprays of insecticide are still required when these pests become economically important. Aldicarb controls walnut caterpillar through October in South Carolina with treatments of 3, 5, 6, and 10 lb ai/acre when applied once on 15 May (Gorsuch and Aitken, 1980). Aldicarb treatment will reduce the number of foliar sprays by 2 or 3 in most areas. There are usually 7 to 8 foliar fungicide and 5 to 6 insecticide sprays in the southeastern United States pecan orchards where aldicarb is not used. In the West fungicide use is greatly reduced and major insect problems are controlled with 1 to 5 foliar sprays. Control of aphids, leafminers and mites may not be required in certain years because the populations never reach damaging population levels. Since aldicarb is applied before insects and mites become a problem, it is used as a prophylactic treatment to avert the risk of pest damage.

Costs of a foliar application of an insecticide were calculated at approximately $4 per acre plus the cost of insecticides from recent estimates by Westberry (1988, personal communication). Elapsed spray time is 28 seconds per tree or 6 minutes per acre. Costs of alternative materials range from $4 to $24 per acre (Table 14).

Higher rates of application are required to control pecan aphids with phosalone or cypermethrin under moderate population levels. The total cost range for material and application is from $12.12 per acre-season for disyston to $32.50 per acre-season for phosalone. Cost of a single application of aldicarb at 5 lb ai/acre is $82 per acre-season plus an application cost of $3 per acre-season or $85 per acre-season.

Economic Impact Caused by Cancellation

An economic analysis of pecan production costs in Georgia (Westberry et al., 1987) is the most recent estimate of a pecan budget. The average total cost of fungicide and insecticide materials was $95 per acre and aldicarb alone can cost $162 for a single application at the maximum rate. However, the typical application will cost $84 to $130 per acre for soil swathe application and $42 to $62 per acre for emitter adjacent application. To remove year-to-year variations, 3 year averages for production, acreage, and improved pecan prices were used. The pecan crop had an average value of $167.5 million per year from 1985-87 (USDA, 1988). Improved cultivars produced 171.6 million pounds from approximately 280,000 acres and these nuts sold for an average price of 72.8 cents per pound. Average crop value for improved pecan is approximately $124.9 million and for native and seedling pecan is approximately $42.6 million.

The use of aldicarb increases yield by 99.8 percent over untreated trees and 48 percent over trees treated with the most efficacious aphicide applied to the foliage when treatments are compared over 3 seasons (Table 15). Sixty-percent of the pecan producing acreage planted to improved cultivars have aphid populations which are difficult to control and indicate that insecticide resistance has developed or is developing (Alverson, McVay, Ellis, Glogoza, personal communications). Resistance development is a dynamic process in the pecan industry and the portion of aphids resistant to foliar sprays depends on the class of insecticide used, the number of applications per season, and the time of season when the applications are made (Dutcher, 1990, personal communication).

In research plots aldicarb treated trees produced 688 pounds per acre; trees treated with foliar aphicide controls produced 503 to 608 lb/acre; untreated trees produced 344 lb/acre (Table 15). Yield reductions were calculated as (yield with aldicarb; yield with alternative; no control) divided by (yield with aldicarb). Use of foliar aphicide controls had yield reductions of 12 to 26 percent. When no aphicides were used, yield reductions were 50 percent. Insecticide resistance or tolerant aphid populations were assumed to cause the same yield reductions as aphids in unsprayed trees. The gross of benefits of current aldicarb use in 10 percent of the improved pecan plantings were calculated as the sum of benefits in orchards without difficult aphid control problems (susceptible acres) and benefits in orchards with difficult aphid control problems (resistant acres). The gross benefits for both the susceptible acres (S-acres) and the resistant acres (R-acres) were estimated by multiplying the acreage by the product of the proportional yield decrease and the average improved pecan price. The net benefits equal the gross benefits minus the gross control cost. The S-acres were assumed to be treated with an aphicide at a cost per acre of $12.12.

```
Total benefit ($) = [(aldicarb treated R-acres)(yield/acre)(price/lb)]
                    x [proportion yield decrease + aldicarb treated S-acres]
                    x [(yield/acre)(price/lb)] x [proportion yield decrease]
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where yield per acre is the yield without any aphicide controls and proportion yield increase is response to aldicarb treatment.

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Gross benefit ($) = [(.098)(.60)(280,000 acres)] x [(688 lb/acre)($.728)(.5)]

                    + [(.098)(.40)(280,000 acres)]
                    x [(688 lb/acre)($.728)(.19)
                    = $4,123,112 + $1,044,522
                    = $5,167,634

Change in control costs ($) = [(aldicarb treated acres)(cost of application)]
                              - [(S-acres)(cost of aphicide)]
                              = $2,199,371

Net benefits = $2,968,263

Crop value = $167,500,000

Benefit as a % of crop value = 1.8%
```

In Georgia, the leading pecan producing state with 150,000 acres and 83 to 125 million pounds of in-shell production per year, insect damage is estimated each year by the extension service. Loss due to the indirect damage of aphid and mite feeding was $9.8 million in 1983, $10.2 million in 1984, $4.9 million in 1985, $1.9 million in 1986, and $2.5 million in 1987 (Univ. of Georgia, College of Agriculture). Control of yellow aphids (*M. caryella*) and black pecan aphid (*M. caryaefoliae*) are related to improved pecan tree productivity (Gentry et al., 1981). Broadcast application of aldicarb, in this study, followed by incorporation with a harrow to 3 to 4 inches was tested at 0, 10, 20, and 40 pounds actual aldicarb per acre. The comparisons are made between untreated acres and those treated with the highest legal rate of aldicarb, 10 lb ai/acre. The treatment reduced yellow aphids by 64 percent, black pecan aphids by 95 percent, and honeydew by 73 percent. In Integrated Pest Management research results (Dutcher et al., 1984) where treatments of aldicarb + methomyl were compared to an untreated control, the insecticide treated plots had consistent good yields for 3 years. Untreated plots had good yields after 1 year of poor aphid control, moderate yields after 2 years of poor aphid control and no yield after 3 years of poor aphid control. Aphid control the previous year has an impact on the current years yield and the benefit of aphid control is realized when aphids are controlled for 2 years or more. Table 15 indicates the best estimates of aphid control benefits with respect to yield. The variation is high between pecan trees and only large differences in yield are detectable in the experiment. Over 3 years, however, yield is reduced by 50 percent (13 kg per tree without aphid control versus 26 kg per tree with aphid control) in trees where aphids are not controlled. The yield loss does not occur until the third year. The grower will benefit from a good yield in the third year of a 3 year aphid control program. The cancellation of aldicarb would remove yield increases of 48 and 99 percent due to foliar insect control, and additional yield increases as high as 20 percent per year from yield enhancement effects over and above the effects of insect control (Alverson, personal communication). Cancellation would also remove total kernel weight increases of 8 percent, and remove increases in the harvested crop in the first shaking. Since these findings are difficult to quantify over all pecan plantings the net benefits are estimated from the results in Table 15 (yield increases due to insect control). The total net benefits and therefore the cost of cancellation are actually higher due to the indirect yield enhancement.

Conclusions and Recommendations

The greatest factor to consider in the integrated management of pecan pests is the dynamic nature of decision-making for insect control. The complex of insects is diverse and has a tremendous damage potential. The occurrence of these insects at economically important levels is determined by scouting insect populations and measuring phenological development of the fruit and foliage. Scouting is required with and without aldicarb treatment as the spectrum of efficacy for aldicarb is limited. The benefit of preventive application of aldicarb when insects within the efficacy spectrum do not develop to damaging population levels, is risk aversion. During years of high aphid and mite populations, aldicarb increased treatment resulting in foliage retention in the fall and increased reblooming of pistillate and staminate flowers in the spring. These effects result in regular bearing of fruit and more consistent yield. Mite control is only fair at the legal rates of application and miticides are usually required if the pecan leaf scorch mite becomes a pest in the fall. The application of foliar sprays causes drift of insecticides to areas outside the orchard as the toxicants are sprayed in a water solution to heights of 60 to 80 ft. Aldicarb reduces the number of foliar sprays by 2 to 3 sprays and can reduce pollution of the environment.

There is a general trend of increased tree vigor where aldicarb is used year after year. Unpublished results from South Carolina (Alverson, personal communication) indicate that aldicarb causes a 20 percent increase in pecan yield each season over and above yield increases expected from aphid control alone. These increases occur when aldicarb is applied over a 5 year period. McVay (personal communication) and H.C. Ellis (personal communication) have seen a significant increase in the percentage of the pecan crop which can be harvested from the first shaking of the trees in aldicarb treated trees. A published report (Dutcher et al., 1984) indicates that aldicarb may increase the percentage of fancy kernels produced by a tree. In 17 treatment comparisons aldicarb treated kernels had a higher quality grade than 9 treatment plots without aldicarb. In 8 treatment comparisons the aldicarb and non-aldicarb treatment had the same kernel quality. Aldicarb treated plants had higher kernel quality than any of the plants that were not treated. Higher tree vigor and increased pistillate and staminate flower production during the following spring is related to good aphid control in the fall. Aphid control by efficacious alternatives to aldicarb will produce these results in the same pattern as aldicarb. In these same experiments of plot comparisons which had a significant yield, aldicarb treated plots had higher yields than plots not treated with aldicarb. The yield records were tied in three comparisons, and the plots not treated with aldicarb had a higher yield in one comparison. Pecan yields are highly variable between trees and the data are difficult to interpret unless they are taken over a 3 year time period.

Summary

The use of aldicarb is beneficial to producers with high yields (greater than 1200 lb/acre) as the cost of material per application ranges from $20 to $130 per acre. Aldicarb treated pecan has a lower amplitude in irregular bearing from year-to-year. The preventive control of aphids may be useful to growers who reside at a remote location from the orchard, or in areas where the aphids are the major pest problem. In most pecan producing states the aphids and other target pests are a small portion of the total pest complex which attacks the crop. Therefore, aldicarb applications are usually supplemented by foliar sprays for nut pests and gregarious caterpillars which are not controlled by aldicarb. In some growing areas pecan aphids have developed insecticide resistance to many foliar applied materials and aldicarb is the only efficacious chemical control. Given the

propensity of pecan aphids for developing insecticide resistant populations to all currently registered foliar sprays, the continuing registration of aldicarb to control these resistant populations is needed by the pecan industry.

Pecan aphids which have become difficult to control with foliar insecticides are controllable with aldicarb, and reduced efficacy of foliar insecticides has been reported in 60 percent of the improved pecan acreage. The gross aldicarb benefit from control of resistant pecan aphids was estimated at $4.1 million.

General insect control and yield enhancement from aldicarb use on the remaining 40 percent of the aldicarb-treated acreage without aphid control problems was estimated at $1 million.

Gross benefits are $5.1 million. Gross control costs of application are $2.1 million for a net benefit of $2.97 million. Total crop value is $167.5 million. Current benefits are 1.8 percent of the total crop value.

Table 11. Pecan production in the United States								
State	Acre in 1982 (x1000)	Production (millions of lbs. in shell)						
		1982	1983	1984	1985	1986	1987	1988
Georgia	116.9	125	100	120	83	120	115	105
Texas*	340.0	38	70	25	78	40	42	45
Arizona	15.8	36	–	–	–	–	14	14
New Mexico	3.4	25	29	24	29	27	25	29
Oklahoma	43.9	82	52	52	51	51	22	7
Alabama	50.0	17	24	13	16	16	25	12
Louisiana	15.1	52	25	15	30	19	30	
Mississippi	15.0	5	8	5.5	6.5	7.5	12	10
Florida	9.8	3	3.4	5	2.8	5.5	4.5	5.5
South Carolina	5.4	2	1.5	5.5	1.4	6.5	3.4	4
Arkansas	7.8	2	2.5	1.5	1.7	1.2	1.3	3
United States**	414.3	252	288	233	261	273	262	273

* Texas acreage includes improved, native and seedling acres which are harvested. The U.S. total does not include the natives. The U.S. total includes 131,200 acres of seedling and improved Texas pecan.
** Other pecan producing states include North Carolina, Tennessee, Missouri, California and Kansas and these states do not use aldicarb.

Table 12. Typical aldicarb application procedures					
Number of applications	Method of application	Time of application	Rate**(lb form/acre)	Target pests	Average cost ($/acre)
Split Application	Soil swathe	1st Nut Set	17-33	Aphids	$42-81
		2nd Mid-summer	17-20	Aphids	$42-49
	Emitter Adjacent	1st Nut Set	17	Aphids	$42
		2nd Mid-summer	8	Aphids	$20
Single Application	Soil swathe	Between Budbreak & Nut Set	17-67	Aphids	$42-162
	Emitter Adjacent	Nut Set to Mid-summer	17	Aphids	$42

** formulated as Temik 15G.

Table 13. Survey results of aldicarb use in states which responded to a questionnaire in 1988

State	% of Acreage		Output**	Rank of purpose of use***		
	Acreage*	Treated	(lb/acre)	insect	nematode	growth
Georgia	150,000 A	15 %	800	1	2	3
Texas	42,000 A	12 %	750	1	2	3
Alabama	50,000 A	20 %	800	1	2	3
South Carolina	6,000 A	15 %	800	1	3	2
Mississippi	20,000 A	1 %	550	1	-	-
New Mexico	27,000 A	5 %	1,308	1	-	-
Florida	12,000 A	6 %	250	1	-	-

* Number of acres of pecan where aldicarb can be used. Label restrictions were sent with the questionnaire. The acreage estimates may be greater than those from Table 11 which were made by census in 1982. The estimates in Table 13 were collected from a 1988 questionnaire.

** Production of in-shell pecan averaged over most recent 5-year record.

*** Purposes are control of insects (and mites), control of nematodes, plant growth regulator effects. "-" indicates that aldicarb is not used for the indicated control purpose.

Table 14. Costs of alternative chemical controls to aldicarb on pecan

Material-Form	$/gal	amount form/acre	$/spray	$/acre-season (2 sprays)
Zolone-3EC	24.50	2.67-4 pts	8.17-12.25	16.34-24.50
Thiodan-3EC	26.50	2 pts	6.63	13.2
Asana-1.92EC	98.90	6.7 oz.	5.15	10.30
Cymbush-3EC	247.17	2.6-4.2 oz.	5.02-8.11	10.04-16.22
Ammo-2.5EC	206.00	3.0-5.0 oz.	4.83-8.05	9.66-16.10
Disyston-2EC	44.00	6.0 oz.	2.06	4.12
Dimethoate-1.67EC	21.00	2 pts	5.25	10.50

*Application costs for foliar sprays cost $4 to $5 per acre to apply for equipment and labor but these costs are dependent on orchard size and variations in labor and equipment costs between regions. The foliar applications require a weekly scouting report for correct timing.

Table 15. Impact of late season aphid control on pecan tree yield

Relative Aphid Control Level	Average Yield (kg/tree)			
	Year 1	Year 2	Year 3	Overall
Poor	16	21	2	13
Moderate	41	17	12	23
Good	27	20	10	19
Excellent	33	24	20	26

*Analysis of variance found a statistically significant difference in year 3 between poor and excellent control levels. All other mean differences were not significant.

Table 16A. Performance of foliar and soil applied insecticides registered for use on pecan which have good aphicidal activity: foliar applied pesticides registered for use on pecan

Foliar Pesticide (b)	lb/ acre	Yellow aphids	Black pecan aphids	Pecan scorch mite	Pecan phylloxeras	Pecan leafminers	Walnut caterpillar	Fall web worm
carbaryl	2.4(c)	4	4	4	1–2	4	1	1
cypermethrin	0.06	2–3	1–2	4	1–2	4		
cypermethrin + chlorpyrifos	0.06 0.25	2	2–3	4	–	4	1	1
cypermethrin + chlorpyrifos	0.06 0.50	2	2	4	–	4	1	1
diazinon	1.0 2.0	2–3 1–2	1 –	2–3 –	– –	4 –	2 –	2 –
dimethoate	0.33	4	1	3–4	3–4	2	2	–
disyston	0.38	2–3	1	2–3	–	2–3	–	2
endosulfan	0.75	2–3	2	2–3	1	–	–	2
Vendex	0.63	–	–	1	–	–	–	–
fenvalerate	0.10	2–3	3	4	1	1	1	1
fenvalerate + chlorpyrifos	0.10 0.50	1–2	1–2	3–4	–	–	–	–
fenvalerate + EPN	0.10 0.25	1–2	1	–	–	–	–	–
fenvalerate + oil	0.10 0.25%	2–3	3	4	–	–	–	–
LV formulation of methomyl	0.9	2	2	–	–	–	1	1
ethyl parathion	0.5	2–3	1	2–3	–	4	1	1
phosalone	1.0	2	1–2	–	2–3	4	2	2

(a) Source: insecticide trials against certain pecan pests conducted by state and federal laboratories. Compiled by J. A. Payne, J. D. Dutcher, and H. C. Ellis in 1988.

(b) For nut and shoot pests: trunk injection of dicrotophos is effective against spittle bugs (rating = 1); aldicarb is not effective against and nut pests at the maximum registered rate of application; foliar sprays have variable nut pest efficacy ratings. The other nut pests are not effectively controlled by these treatments (ratings range from 3-4). Nut pest control is an added benefit of alternative chemical controls when they are chosen over aldicarb application.

(c) CONTROL RATINGS ARE: 1 = 95-100% "excellent"; 2 = 80- 94% "good"; 3 = 70- 79% "moderate"; 4 = <70% "Poor; – = no information available.

16B. Performance of foliar and soil applied insecticides registered for use on pecan which have good aphicidal activity: soil applied and trunk injected insecticides

Pesticide	lb./acre	Yellow aphid	Black pecan aphid	Leaf scorch mite	Pecan leaf miners	Leaf phylloxeras	Walnut caterpillar	Fall web worm
aldicarb	6.0* 1	1	2	1-2	-	4	4	
aldicarb	2.5 &	1	1	1-2	1-2	-	-	-
dicrotophos	2.0z#	2	2	3-4	4	1	1	1

* applied in the soil to a depth of 2 inches in a swathe in the tree row.
& applied adjacent to the emitters of the drip irrigation system.
# applied as a trunk injection at 2.0 grams actual insecticide per 15 cm of trunk and scaffold limb circumference.

Vegetable Crops

Aldicarb Use on Dry Beans

Vernon E. Burton

Dry beans are produced commercially in 14 states, located primarily in the North-Central and Western United States. The principal production states include Nebraska, California, North Dakota, Colorado, Idaho, and Michigan. Harvested acreage has averaged 1.5 million acres between 1986-88 with an estimated value of $431.1 million in 1986. Pinto bean dominates production, however, large acreages of navy, great northern, and red kidney beans are also produced. The market price of dry beans is highly volatile. Prices average approximately $25/cwt, but commonly fluctuate 50 percent or more. Prices received vary among growing regions. For example, average prices of California beans was $26.33/cwt during 1984-86 while prices in Colorado averaged $16.17 during the same period. Growing conditions in production regions and export demand also are important in determining market price. Bean quality is also important in determining price of dry beans. Off-color, spotting, or shriveling are common defects that can be caused by insect or mite infestation.

Registration Summary

Aldicarb is labelled for use as a planting time treatment to be applied at rates of 1 to 2 lb pounds active ingredient (lb ai) per acre. Special Local Need 24(c) registrations for sidedress treatments have been granted for California, Oregon, Washington, and Idaho to control lygus bugs and spider mites. Aldicarb is labelled for control of several insect pests including seedcorn maggot, aphids, leafhoppers, Mexican bean beetle, mites, and nematodes. A Special Local Need 24(c) registration has been granted for lygus bugs. At present, most aldicarb applications are made to control spider mites or lygus bugs in California and the northwestern growing areas.

Pest Infestation and Damage

Spider Mites: Several species of spider mites infest beans including the two-spotted spider mite, Pacific spider mite, and the strawberry spider mite. Feeding by mites decreases photosynthesis of plants and can cause premature leaf drop. In Idaho, spider mite control is considered critical 3-5 weeks prior to harvest (Bechinski and Stoltz, 1985). Sidedressed aldicarb treatments have provided yield increases of 7 cwt/acre compared to untreated controls (Stoltz, 1978). In California, short-season beans typically have little yield loss resulting from infestations of spider mites, which tend to occur late in the growing season. However, long season beans (e.g., lima beans) are highly susceptible to spider mite damage (Vernon Burton, University of California-Davis, personal communication, 1989). Although most effects of spider mite injury result in yield reductions, quality may also be affected. On certain pink and red bean varieties, California growers report off-coloring from mite infestations which is a grade defect resulting in lower crop value.

Lygus Bugs: *Lygus* spp. plant bugs feed upon blossoms and developing bean pods. Feeding injury induces blossom abortion and reduces seed set. When small, developing beans are fed upon they may continue to grow but are often shrunken or discolored. Severity of lygus damage is inversely related to the length of the growing season: long season beans sustain greatest damage from lygus bugs. For example, a 1978 University of California at Davis trial showed a 11.8

cwt/acre increase from treatment (9.7 cwt compared to aldicarb) on lima bean, a long growing season bean (Vernon Burton, University of California-Davis, unpublished data).

Nematodes: Root-lesion nematodes (*Pratylenchus* spp.) are widely distributed throughout areas of commercial dry bean production. Root-lesion nematodes feed upon plant roots, reducing vigor and yield. Above-ground symptoms of stunting or discoloration may be noted. At least nine different species have been reported to feed upon dry beans. However, the penetrans root lesion nematode, *Pratylenchus penetrans*, is the species best documented as being seriously damaging to dry beans. Susceptibility to nematodes varies by variety. For example, yield increases from aldicarb treatment of nematode-infested dry beans ranged from 35 percent to 216 percent among 5 navy and kidney bean varieties tested in Michigan (Elliot and Bird, 1980). Serious nematode problems on dry beans are uncommon throughout most of the dry bean production areas of the country. Aldicarb treatment is limited to use on navy beans in Michigan, although other labelled pests of the crop occur in the state. Economic thresholds for *P. penetrans* have been developed in Michigan (Elliot et al., 1982).

Leafhoppers: Several species of leafhoppers commonly infest beans. In the North-Central States (including Michigan), potato leafhopper (*Empoasca fabae*) is the most common. Visible foliar symptoms of yellowing and stunting are commonly observed. However, yield losses to beans are rarely demonstrated.

Mexican Bean Beetle: Mexican bean beetle is the most common insect that chews on foliage in the North-Central States. Over most of the area, economically damaging infestations are irregular. High populations tend to occur in late season, causing little injury. Defoliation injuries during periods of seed set and early pod fill have greatest potential to cause yield loss.

Seedcorn Maggot: Seedcorn maggot is a seedling pest that can reduce stand. Problems occur in high organic matter soils, particularly on land with large amounts of decaying plant material or animal manures. Planting in cool soils also aggravates injury.

Pest Management

Spider Mites: Aldicarb is labelled for control of spider mites as a planting time treatment at the rate of 1-2 lb ai. Sidedress applications at a rate of up to 2 lb ai are allowed in Idaho, Washington, Oregon, and Washington under a 24(c) registration. Little recent published information is available comparing effectiveness of aldicarb to alternatives. Aldicarb is reported to currently be an effective treatment in Idaho (Bob Stoltz, University of Idaho, personal communication, 1989) and California (Vernon Burton, University of California-Davis, personal communication, 1989). Cultivation treatments at a 1 lb ai/acre rate predominate in Idaho; a 2 lb ai rate is common in California.

Dicofol and propargite are the alternative treatments. The effectiveness of these chemicals is comparable to aldicarb. Dicofol is the primary chemical alternative used by producers. Application rates are 1.5 lb ai/acre. The cost of dicofol ($17.36 + $4 application) is higher than aldicarb, but is applied on a need basis rather than as a preventive treatment. However, the effectiveness of dicofol may be inadequate if applications are made during late stages of outbreaks. Dicofol also is less effective when temperatures are high. Propargite has similar cost and efficacy limitations as dicofol. Estimated cost (3 pints Comite/acre @ $18.89 + $4 application) is considered high and effectiveness is greatest when applied during early stages of outbreaks.

Spider mites have repeatedly become resistant to a wide range of pesticides applied for their control. Because of the limited number of pesticides effective against spider mites on dry beans (or any crops), there is additional value to aldicarb in managing resistance development.

Lygus Bugs: Applications of aldicarb, at 2 lb ai sidedress, can protect dry beans in California through early blossoming. On short-season varieties, this may be sufficient to maintain yield; 1-2 supplementary treatments may be required on mid- and long-season dry bean varieties.

Acephate and dimethoate are alternative lygus treatments. Treatment costs per acre are in the range of $12.73 (Orthene 75S, 1 lb ai + $4 application cost). On long-season varieties, three treatments are typically required; two treatments on mid-short season varieties; and one application for shortest season varieties. In California, both dimethoate and acephate can aggravate spider mite problems. On long-season varieties, this can induce economically damaging infestations that require supplementary controls.

Nematodes: Yield response from nematode control has been demonstrated in Michigan, where *Pratylenchus penetrans* is a widespread problem. Navy beans are particularly susceptible to nematode damage, although some kidney beans also have responded from treatment. For nematode control, aldicarb is applied at 1-2 lb ai, as a planting time band. Recent data from Idaho (Hafez, unpublished data, 1988) did not indicate a yield benefit from use of aldicarb for control of nematodes. This trial involved *Pratylenchus neglectus*, which is considered to be less damaging than is *Pratylencus penetrans* (George Bird, Michigan State University, personal communication, 1989).

Alternative nematicides are not viable alternatives for most producers. Metam-sodium is highly effective but very expensive ($250/acre).

Development of resistant varieties is a long-term alternative practice. Some varieties are tolerant of nematode injury and do not respond with increased yield from nematicides, while a varying response occurs on other varieties (Elliot and Bird, 1985).

Leafhoppers and Mexican Bean Beetle: Aldicarb can control damage by Mexican bean beetle and potato leafhoppers through much of the season. However, numerous alternative controls exist: esfenvalerate, disulfoton, azinphos-methyl, acephate, methyl parathion, oxydemeton-methyl, carbaryl, endosulfan, dimethoate, diazinon, naled, and trichlorfon. Most of these alternatives are foliar treatments that can be applied on an as-needed basis, in contrast to preventive aldicarb applications. The alternative planting time treatment (disulfoton) is approximately one-third the cost of aldicarb. Little or no current use of aldicarb was reported for control of these insects since alternatives are less expensive.

Seedcorn Maggot: Aldicarb can control seedcorn maggot. A much cheaper alternative is seed treatment with chlorpyrifos. No aldicarb applications are currently made for seedcorn maggot control.

Current Chemical Usage

California: Lygus bugs and spider mites are the key pests controlled by aldicarb. An average of 1.4 percent of the acreage is treated, approximately 6,622 acres based on average 1986-88 acreage. Yield benefits, compared to alternatives, have not been demonstrated. Sidedress

applications of aldicarb (2 lb ai) are assumed to replace one foliar application for control of lygus bugs (acephate @ $12.73) and one foliar application for spider mites (dicofol @ $21.36). This gives a treatment cost differential compared to aldicarb ($31.74) of $2.35/acre. The aldicarb treatment cost ($431.74/acre) is $2.35 less than the combined acephate-dicofol treatment alternative ($34.09/acre). Net value of aldicarb on currently treated California acreage is estimated at $15,561 (6,622 acres @ $2.35/acre).

Idaho: Aldicarb is applied for control of spider mites in areas where chronic mite problems occur. Approximately 10-15 percent (12.5 percent) of the acreage is treated, a figure that has remained steady for several years. Based on average 1986-88 harvested acreage, approximately 16,916 acres receive treatment annually. Treatments are recommended for areas with perennial spider mite problems, using a sidedress application of aldicarb at 1 lb ai. University of Idaho data (Hafez, 1988) does not support a significant response from nematode control. Treatments on dry beans rotated with sugarbeet can get some additional benefit by further suppressing sugarbeet cyst nematode during crop rotation. Aldicarb is assumed to substitute for one foliar application for spider mite control. Treatment cost differential of aldicarb ($15.87) and the dicofol alternative ($21.36) is $5.49/acre. On currently treated acreage, net value to Idaho growers is estimated at $94,247.

Michigan: Root-lesion nematodes are problems on navy beans grown on sandy loam soils. Very little acreage (3,150 acres, 1 percent) is estimated to be treated with aldicarb. Michigan State University research has demonstrated a significant increase in yield from nematode control on navy beans grown in infested sandy loam soils (George Bird, Michigan State University, personal communication, 1989). Aldicarb is not recommended for control of insects since occasional insect problems are easily controlled with alternatives (Robert Ruppel, Michigan State University, personal communication, 1989). Rhone-Poulenc reports an average 4.61 cwt increased yield in nematicide trials. This response seems well within reported state university data (Elliot and Bird, 1980a, 1980b and 1985) and is used for benefit estimation. Increased yield on treated acreage is estimated at 14,521.5 cwt, valued at $288,978 ($19.90/cwt). Net value (minus $31.74/acre treatment cost) is $188,997. There are no alternatives for nematode control on the limited acreage where problems occur.

Washington: Treatments are applied for control of spider mites. Recommended application is 1 lb ai, applied as a sidedress treatment at cultivation ($15.87). There is no evidence for yield benefit compared to existing alternatives. Data on use is unavailable but production is contiguous with Idaho and is assumed to be similar. An estimated 10-15 percent of the acreage is treated, approximately 4,375 acres. Applications substitute for one foliar application of dicofol ($21.36). Treatment cost differential of $5.49 gives a net value of $24,019.

Summary and Conclusions

Aldicarb is used on dry beans is as a nematicide in Michigan, an acaricide in Idaho-Washington, and as an acaricide-insecticide in California. Aldicarb usage is relatively minor on dry beans. Approximately 31,063 dry bean acres were treated with aldicarb in 1988. Use has been fairly steady in recent years. Michigan obtains the greatest benefit from aldicarb use ($188,997), where it is used to control the sting nematode *Pratylenchus penetrans* on navy beans. There are no alternatives to aldicarb for nematode control in Michigan since metam-sodium fumigation is prohibitively expensive. Absence of aldicarb would likely prohibit navy bean production on this

acreage. In Idaho, Washington, and California aldicarb is used as sidedress treatment. It is less expensive than the alternative foliar sprays, resulting in an annual savings to growers estimated at $132,449. Aldicarb is considered to be very important in helping to manage pesticide resistance among spider mites. Few alternative treatments exist and spider mites have become resistant to many pesticides in the Western states.

An estimate of the national benefits arising from the use of aldicarb in the production of dry beans can be generated by examining the changes in the value of production and control costs at the state level. This analysis is restricted to valuations of yield losses and changes in control costs. Implications of quality, market price adjustments, and resistance management have not been taken into consideration. Tables 17 and 18 summarize the results of the analysis. The 3 year average (1986-88) of harvested acreages for each state is shown with an estimate of the number of acres treated with aldicarb. For the four states reporting aldicarb use, the net benefits are presented in Table 18. Predominant benefits demonstrated for California, Idaho, and Washington are for reducing treatment costs. Resistance management for spider mites is another expressed, but unquantified, benefit to these areas. Significant yield losses would result from aldicarb cancellation in Michigan. If aldicarb were no longer available to dry bean producers, the immediate annual net loss is estimated at $321,446.

Table 17. Summary of estimated aldicarb use on dry beans

State	Average harvested acreage, 1986-88[1]	Estimated aldicarb treated acreage, 1986-88
California	157,000	6,622
Colorado	173,333	-0-
Idaho	135,333	16,916
Kansas	22,667	-0-
Michigan	315,000	3,150
Minnesota	65,000	-0-
Montana	4,733	-0-
Nebraska	198,333	-0-
New Mexico	10,250	-0-
New York	28,000	-0-
North Dakota	336,333	-0-
Utah	6,567	-0-
Washington	34,000	4,375
Wyoming	32,667	-0-
Total	1,519,216	31,063

[1] Source: Annual Crop Production figures, January 1989. Agricultural Statistics Board, NASS, USDA.

Table 18. Estimated annual yield and economic benefit, compared to alternative, from aldicarb use on dry beans

State	Change in production	Change in value of production ($)	Change in control costs ($)	Net benefit ($)
California	-0-	-0-	15,561[1]	15,561
Idaho	-0-	-0-	92,869[2]	92,869
Michigan	14,521.5	288,978	-99,981[3]	188,997
Washington	-0-	-0-	24,019[2]	24,019
Total	14,521.5	288,978	32,468	321,446

[1] Aldicarb application at 2 lb ai ($31.74) compared to application of acephate ($12.73) and one application of dicofol ($21.36).
[2] Aldicarb application at 1 lb ai ($15.87) compared to one application of dicofol alternative ($21.36).
[3] Increase in yield of 4.61 cwt on treated acreage at $19.90 cwt. Treatment costs of 2 lb aldicarb ai are $31.74. There is no nematicide alternative. Treatment cost differential compared to untreated.

Aldicarb Use on Potato

James Bowman, Mark Graustein, Saad Hafez and Gary D. Kleinschmidt

Potato is commercially grown on over 1.2 million acres throughout the United States. Commercial potato production occurs in 38 states, with primary production in the Pacific Northwest (Idaho, Washington, Oregon) and North-Central region (North Dakota, Wisconsin, Minnesota, Michigan). Individual states with large potato productions include Maine, Colorado, and California. Significant seed potato production occurs in a more restricted area. Primary seed production states include Idaho, North Dakota, Maine, Minnesota, Colorado, Montana, Nebraska, and Wisconsin. Production and value have increased steadily with current U.S. production of over 300 million hundred weight (cwt) with 1986 value exceeding $1.64 billion. The fastest growing area of potato utilization is in processing as french fries, chips, shoestrings, for canned foods, or flakes. In recent years, this market also has had substantially increased export sales, particularly in frozen products sold to Asia. Another one-third of the U.S. crop is utilized in fresh market (table stock) sales. Seed potato accounts for 6 to 8 percent of total production. Minor potato uses include livestock/fish feed, alcohol, and starch flour production. Shrinkage and loss of the crop in storage have ranged from 7 to 13 percent in the past decade.

Prices of potato are generally inversely related to production. Average U.S. potato prices have varied from $3.38 to $5.82/cwt in the past decade. However, prices received during specific marketing periods can vary widely from these average figures, depending on demand. Potato produced and marketed during spring and early summer often command the highest price. Incidence of grade defects are extremely important in determining price. Necrotic areas, tunneling injuries, and factors that adversely affect storage or processing may be sufficient to keep potato from being successfully marketed. Potato with levels of defects that exceed market standards are considered culls and can not be sold in fresh market (table stock) or processing potato markets and receive a very low price (typically less than $1.00/cwt) for alcohol production, livestock feed or other marginal markets.

Seed potato, produced under strict sanitation conditions to reduce incidence of disease and subject to state certification, have a considerably higher value. Those that have recently been cultured from completely disease-free stock may be priced several times greater (up to $100/cwt) than the table stock/processing crop. Subsequent generations of seed potato are of lesser value and may only be sold at a price that is $1 to $3/cwt higher than the commercial crop. As with table stock and processing potato markets, seed potato prices are highly volatile.

Pest Infestation and Damage

<u>Colorado Potato Beetle:</u> The Colorado potato beetle, *Leptinotarsa decemlineata*, is the most destructive pest of potato in most Eastern and North-Central states. Colorado potato beetle adults and larvae feed on potato foliage and plant stems. This damage reduces the photosynthetic capability of the plant, resulting in a decrease in size and weight of tubers. Potato production is most limited by Colorado potato beetle damage in the Northeast, where insecticide resistance development is extreme (Gauthier et al., 1981). Severe resistance problems occur in the mid-Atlantic states and have greatly increased in the North-Central states in recent years. Evidence

of resistance problems has been detected in laboratory bioassays of beetles from the North-Central and Mountain states (Gauthier et al., 1981; Johnston and Sandvol, 1986; Radcliffe and Watrin, 1986; Grafius et al., 1988), although insecticide failures due to resistance have not yet been observed.

Potato production is most severely limited by Colorado potato beetle in the Northeastern states. Extreme levels of resistance to essentially all registered pesticides occur in parts of this region. Control costs and Colorado potato beetle injury, along with changes in land values and use, have contributed to abandonment of potato acreage in the Northeast. In the past 5-years Colorado potato beetle has become the most important pest of potato in some mid-Atlantic and North-Central states (G. Zehnder, unpublished data; Radcliffe and Watrin, 1986; Grafius et al., 1988). The pest status of Colorado potato beetle in each region is typically related to the frequency and duration of past insecticide use. It is reasonable to assume that the importance of Colorado potato beetle to U.S. potato producers will increase in many areas where it presently is of minor importance.

Flea Beetles: Several species of flea beetles (*Epitrix* spp.) feed upon the U.S. potato crop. Primary injury occurs from adult feeding which results in small holes ("shotholes") being chewed in foliage. Severe infestations can result in yield reductions due to photosynthetic loss. Flea beetle adults can transmit several diseases to potato including potato ring rot and potato virus X. Problems are most severe in areas where regular sprays are not made for control of Colorado potato beetle and other potato pests. Serious injury is rare, and primarily involves western species of flea beetles that tunnel into tubers. Some future increase in flea beetle problems is likely. Residues of banned organochlorine insecticides (aldrin, dieldrin, etc.) in soils continue to decline, but have until recently been persisting adequately to assist in flea beetle control. Reductions of Colorado potato beetle treatments, or use of selective Colorado potato beetle controls, such as *Bacillus thuringiensis* ("tenebrionis" or "san diego" strains) will also provide lesser levels of incidental flea beetle control. Although the first potato insects to become resistant to DDT, flea beetles have not shown high levels of insecticide resistance development.

Leafhoppers: Potato leafhopper (*Empoasca fabae*) damages plants by injecting saliva during feeding that is toxic to the plant. The intermountain leafhopper, *Empoasca filamenta*, occurs in the western production areas. Feeding by this species is far less injurious to potato, resulting in scattered foliage flecking with little demonstrated impact on yield. The aster leafhopper, *Macrosteles fascifrons*, is also associated with potato. Aster leafhoppers can transmit the disease agent (mycoplasma) which causes aster yellows, called "purple top" disease of potato. Potato leafhoppers are widely distributed throughout the potato production areas east of the High Plains. Consistent high levels of infestation occur in the Upper Midwest production areas of Michigan, Wisconsin, Minnesota, and North Dakota. Problems are more sporadic in the East. In the absence of controls, plants are killed by potato leafhoppers 4 to 8 weeks before normal expectation in the heavily infested areas of the Midwest. Sharp reductions in yield, often exceeding 30 percent, are associated with leafhopper injury in these areas. An action threshold level for treatment (10 nymphs per 100 leaves) has been proposed for Minnesota; a lower threshold is practiced in Wisconsin.

Aphids: Several species of aphids are associated with potato including the green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), foxglove aphid (*Acyrthosiphon solani*), and buckthorn aphid (*Aphis nasturtii*). The most important injury caused by aphids to the crop is the transmission of various virus diseases such as potato leafroll and Potato virus Y. Yields of potato crops planted with 1 percent leafroll infected seed are reduced 0.5 to 1 percent. Control

of these diseases is of extreme importance in seed production. Disease levels which exceed certification tolerances (typically less than 1 percent) subject the crop to certification rejection. Need to control levels of aphid transmitted virus disease was a major reason for establishing seed certification standards in the U.S. potato industry. Aphid transmission of viruses to table and processing potato is less important, since yields are little reduced by "current season" infections. An important exception occurs with potato leafroll infection of certain russet cultivars, including 'Russet Burbank'. In susceptible cultivars, infection can result in necrosis of the tuber phloem, resulting in a condition known as net necrosis. Net necrosis is a serious grade defect, particularly for processing potato. Levels of total tuber defects, including net necrosis, that exceed 6 percent are rejected by processors. When accepted, tubers with net necrosis require 20 to 25 percent additional trimming during processing. Rarely, aphids reduce potato yields through feeding injury. However, sustained high aphid populations are very unusual except where disruptive use of fungicides and insecticides destroys natural enemies.

Aphid control costs are associated with essentially all seed productión areas in the United States. Virus related rejections have exceeded 2 percent of the total U.S. seed acreage in recent years, although most have involved mechanically transmitted diseases such as PVX. Losses to processing potato from net necrosis have primarily involved the California and Pacific Northwest areas. Recent trends in seed potato production in almost all areas of the country have involved switching to a "limited generations" system. These seed productions involve maintaining a constant flow of new seed stocks generated from disease-free tissue culture practices. Incidence of virus diseases is greatly reduced by these practices, resulting in reduced incidence of aphid transmission of disease.

<u>Stubby Root Nematodes/Corky Ringspot:</u> Stubby root nematodes (*Trichodorous* spp., *Paratrichodorous* spp.) transmit the virus disease tobacco rattle virus, which cause the potato disease known as corky ringspot. Corky ringspot infected tubers show characteristic necrotic rings or arcs, resulting in a serious grade defect. Incidence of corky ringspot problems are widely scattered, particularly on more sandy soils. The disease has been reported from eight states with severe endemic problems in the winter potato production area of Florida (approximately 28,000 acres). Some 200 acres of summer potato in Colorado are also affected and infestations are reported in the Klamath County area of Oregon. In these areas, total potato losses would occur in the absence of nematode controls. Past expansion of areas sustaining significant losses to corky ring spot has probably occurred by moving infected nematodes in soil or on plant materials. There is no evidence of any recent significant increase in affected areas.

<u>Root Lesion Nematodes/Early Dying:</u> At least 15 species of root-lesion nematodes (*Pratylenchus* spp.) are associated with potato production. Direct injuries involve reduction of tuber size and weight. In addition, some species of root-lesion nematodes feed directly on potato tubers, rather than roots, causing reduction in tuber quality. Indirect injuries associated with root-lesion nematode infestations include weakening the plant, resulting in increased susceptibility to other pathogenic organisms. Potato researchers have noted an increase in fungal diseases, such as *Rhizoctonia* and *Verticillium*, correlated with root-lesion nematode infestations. This interaction of nematodes and fungal diseases have been demonstrated during control trials. *Pratylenchus penetrans* is the species of sting nematode that is most often associated with early dying. Different species of *Pratylenchus* have varying potential to cause injury. The root lesion nematode, *P. penetrans*, is the species that has most frequently been associated with serious potato injuries. Potato early dying, a disease complex associated with *Pratylenchus-Verticillium* (Rowe et al., 1987), has received greatly increased attention in recent years. Plants prematurely die and yields are

decreased. Only certain species of *Pratylenchus* (notably *P. penetrans*) predispose plants to *Verticillium* infection and early dying. Infection with blackleg bacteria (Rowe et al., 1987) may aggravate the severity of the disease. Root-lesion nematodes can cause significant direct injury by lowering plant vigor, reducing tuber size and quality. Yield reductions of 10 to 50 percent have been associated with heavy infestation of root-lesion nematodes in potato fields (Jensen et al., 1979). Potato early dying, generally a result of *Pratylenchus-Verticillium* interaction, tends to increase in severity with continuing potato production. Gradual declines in yield have been associated with this disease in the upper Midwest; rapid development of serious losses from the disease have occurred in the Pacific Northwest.

Root-Knot Nematodes: Root-knot nematodes (*Meloidogyne* spp.) damage potato while feeding on roots. Feeding injuries produce distortions of tubers causing serious grade defects. Yields may be decreased. Three species of root-knot nematodes commonly occur as pests in U.S. potato acreage: the northern root-knot nematode, *M. hapla*, the southern root-knot nematode, *M. incognita*, and the Columbia basin root-knot nematode, *M. chitwoodii*. Although distributed throughout most of the United States, root-knot nematodes tend to have more economic impact in warmer regions, particularly on sandier soils. Southern root-knot nematode has been shown to reduce potato yields by 20 to 80 percent. Northern root-knot nematode is considered a serious problem in Michigan and parts of the Pacific Northwest. Recently, discovery of the Columbia Basin root-knot nematode in the Pacific Northwest, has caused considerable concern. This species is adapted to reproduction on grain crops, as well as potato, thus limiting the value of small grain-potato rotations for control. It is also a cool season nematode that has great potential to damage yield and quality of potato.

Importance to Seed Potato Quality

Aldicarb is widely recognized as the most effective soil applied systemic aphicide currently registered for use on potato. Planting-time or sidedress treatments can provide control for 6 to 8 weeks in most locations. Persistence of effects is substantially longer than the alternative treatments of phorate or disulfoton. Since aphid flights typically increase during late season, persistence is a desirable attribute for aphid control. In Wisconsin, several studies have been conducted regarding effectiveness of aldicarb for controlling potato leafroll transmission. In a 3-year study by Bauernfeind (1977) incidence of leafroll spread on aldicarb treated plots averaged 7 percent, leafroll in phorate treated plots was 12 percent, leafroll spread in oxamyl treated potato 12 percent, leafroll spread in disulfoton treated plots was 6 percent, and weekly foliar applications of methamidophos resulted in average infection of 13 percent. Leafroll infection in the untreated check averaged 26 percent. Greenhouse trials with potted plants (Villacarlos, 1983) indicated that some reduction in leafroll transmission was possible from treatment with all of the systemic insecticides (aldicarb, phorate, disulfoton, carbofuran). This occurred when either the source plant or the inoculation host was treated with insecticides. Effective control was greatest when aphids were allowed only 30 minutes to acquire or transmit the virus, rather than 24 hours.

Field studies indicated that aldicarb killed aphids for a longer period than did phorate or disulfoton. Average mortality of aphids placed on plants at weekly intervals during the 6 weeks following application were aldicarb—60 percent, disulfoton—36 percent, phorate—32 percent, and carbofuran—6 percent. High levels of leafroll control were also reported in Idaho studies conducted during 1969 and 1970 (Powell and Mondor, 1973). Substantial reductions in leafroll spread by aldicarb were documented in these studies, in excess of 80 percent of that in disulfoton or phorate treated plots. Three to five foliar endosulfan sprays did not provide control in these

studies. This study provides some of the strongest published evidence of the ability of aldicarb to suppress leafroll. However, contradictory findings on leafroll suppression where reported in California (Bacon et al., 1976). In these trials, conducted over 4 years, no treatments effectively controlled potato leafroll in the Tulelake production area. Incidence of leafroll varied widely over the course of the experiment. In all 4 years, aldicarb treated potato had numerically higher leafroll incidence than did the untreated check.

In New York, use of aldicarb was eliminated prior to the 1987 growing season. Prior to that date, aldicarb was used on over 95 percent of the seed potato acreage. Leafroll incidence averaged 1.2 percent in 1987-88 in contrast to 0.5 percent in 1985-86 (Joe Osmeloski, New York Seed Certification, personal communication). This difference is, in part, due to some unusual growing conditions during 1988, when hot dry weather prompted many growers to extend the growing season of the potato. However, data is also suggestive of positive leafroll suppression from aldicarb. Observations in Colorado during the high leafroll years of 1982-83 indicated that using aldicarb resulted in a lower rate of leafroll. The amount of benefit was not quantified. Since 1983, leafroll incidence has dropped off greatly and there were no field rejections for leafroll in 1988 (Rob Davidson, Colorado State University, personal communication).

In Wisconsin, leafroll incidence has been little affected in the past two years since essentially all aldicarb uses were eliminated in the state. However, recent leafroll incidence in the seed crop, a prerequisite for leafroll spread, has been maintained at very low levels in the seed producing regions. An analysis of Wisconsin seed lot rejections in 1972, a high leafroll year, classified leafroll incidence in seed fields relative to systemic insecticide treatment. This data, submitted by Rhone Poulenc in their benefits assessment, showed much lower rejection rates on aldicarb treated seed potato than on potato treated with phorate or disulfoton. Part of the difference in Wisconsin may be related to the other seed quality protection practices. Several state certification personnel across the country observed that most aldicarb use occurs among the "better" seed growers, who have lower leafroll incidence in general. However, the data does indirectly support the potential value of aldicarb to help control potato leafroll.

It should be noted that aldicarb, and other aphid controls, applied to commercial production fields may indirectly help maintain low leafroll infections in seed fields. This is due to control of aphids that might otherwise migrate from those fields into seed fields. This would be of greatest importance where seed acreage is close to commercial acreages. This situation exists in a substantial portion of the seed potato acreage in Maine, Minnesota, North Dakota, and Idaho.

Several other diseases also affect seed potato quality, some of which are of much greater importance to seed potato quality. Potato virus X (PVX) and bacterial ringrot are mechanically transmitted diseases that are very important in seed potato quality. Insects are involved in little or none of the transmission, which occurs primarily from brushing leaves and movement of machinery through fields. However planting time treatments of aldicarb may limit some machines spread disease by eliminating some foliar applications. This is particularly important in small acreages where aerial applications are not possible. In most U.S. seed potato areas, relatively large acreages occur which allow insecticide applications to be made aerially or via chemigation. Where this occurs, potential for mechanical transmission during insecticide applications is reduced. Insects are more intimately involved in transmission of potato blackleg, a common bacterial disease of the crop (Harrison et al., 1980). Flies and other mobile insects which visit and feed upon decaying organisms are the most frequent vector. However, the importance of insects in this disease may be slight since bacterial blackleg is also spread mechanically and in irrigation water.

Some other viruses, such as potato virus Y (PVY), are also transmitted by aphids. However, because PVY is transmitted during very brief (less than 1 minute) feeding probes, no insecticides have been able to mitigate transmission of these viruses.

Chemical Alternatives for Pest Management

The only consistently effective alternative insecticide for control of green peach aphid on potato is methamidophos applied as a foliar treatment at a rate of ¾ pound active ingredient (lb ai) per acre. Cost of this treatment is high, approximately $9.05 per acre (chemical plus application costs). Two to three applications may be required to provide season-long control, sometimes following a planting time treatment of disulfoton or phorate to provide some early-season protection. On small acreages, methamidophos must be applied with ground equipment, thereby increasing potential for spread of mechanically transmitted virus (PVX) and bacterial (ringrot) diseases. Since methamidophos remains the only reliably effective alternative to aldicarb, removal of aldicarb will increase methamidophos use. This has serious implications for development of resistance.

Non-Chemical Management Alternatives

Field Isolation: Isolation of seed production areas is a highly effective control that is practiced in most seed producing areas. Fields may also be isolated from the overwintering hosts of aphids; green peach aphid typically uses various *Prunus* spp. trees to overwinter. Ability to isolate fields is limited by the amount of land available to the grower. Large amounts of seed produced in states such as Maine, Colorado, Idaho, Oregon, Minnesota, and North Dakota are relatively close to commercial potato production fields. For these areas, reduced ability to control aphid transmitted virus diseases can greatly increase production risks. These risks are further increased if aphid control in nearby table stock/processing fields is reduced, thus increasing the numbers vectors in the region.

Roguing: Removal of infected plants through regular field surveys by growers has long been a component of seed potato production. This costly practice can be expected to increase with additional restrictions on alternative controls. One limitation of roguing is that visible foliar symptoms from infection must occur before infected plants can be identified. This is often not possible with leafroll infections spread during the current growing season. A delay of one growing season between infection and detection can allow sources of infection to remain longer within a crop.

Seed Certification: Strict seed certification standards are in place in nearly every state which establish maximum tolerances for disease that can not be exceeded. This system has greatly reduced the incidence of disease in both the seed and commercial production. Most seed producing states have further restricted production by enforcing limited generation systems. These allow potato grown for seed to have only a limited number of generations in fields after planting of tubers that meet standards for disease-free quality (usually less than 5 years). This limited field exposure to potential diseases has the effect of periodically flushing out seed stocks. The introduction of tissue culture propagation techniques has provided potato seed producers with an important new tool for reducing virus incidence. Original plants are propagated from tissue culture stocks that are known to be free of all disease and the number of subsequent field propagations are limited. Strict seed production standards have reduced the incidence of potato leafroll and other diseases in seed potato. This has a positive benefit of reducing the chance that aphids will acquire the virus and subsequently transmit it to other plants. However, plantlets generated

through tissue culture, and the early generation seedstocks propagated from these plantlets, require a large investment by producers. Tissue cultured plantlets may cost $.50 to $.80 apiece, a total of $10,000 per acre. Progeny tubers from these plantlets may command a price that is many times greater (up to $100/cwt) than subsequent generations. Very strict disease-free standards are required of these early generation seed stocks. In Idaho, there is a 0 percent tolerance for nuclear and first generation seed stocks. Certification standards are not met if two leafroll infected plants per acre are found. For this reason, producers feel it necessary to use all available controls to protect early generation potato. The importance of protectant insecticide treatment to these early generation seed potato is made more important by the increased susceptibility of the potato to infection by aphid-vectored viruses. This occurs because early generation potato are often planted at lower plant densities. This increases the likelihood of infection.

Comparative Performance Evaluation

Colorado Potato Beetle: Aldicarb has consistently been among the most effective controls for Colorado potato beetle. In the Eastern states a high level of control is achieved against overwintered adult beetles, lasting a month or more after application. Alternative planting time or sidedress treatments with phorate, disulfoton, or carbofuran are much less effective than aldicarb in areas where resistant Colorado potato beetle pest pressure is high. These alternatives perform adequately, and cost less, in midwestern and western production regions where Colorado potato beetle is susceptible to most insecticides and is more easily controlled. At present, in areas west of Michigan and Ohio, the demonstration of insecticide resistance has been confined to laboratory bioassays and has not yet been observed in fields.

Several foliar treatment alternatives also exist. In the Midwest and West, various pyrethroid insecticides (esfenvalerate, permethrin, etc.) are predominantly used. In the eastern production region, oxamyl, rotenone, endosulfan, carbofuran, and pyrethroids are all effective treatments. New strains of *Bacillus thuringiensis* (var. *tenebrionis*, var. *san diego*) appear to be effective against young beetle larvae. Sodium fluoaluminate is another very promising insecticide for control of resistant beetles, but use is currently limited to Section 18 registrations. At present, some combination of foliar sprays applied 3 to 7 times per season can provide comparable control in most areas. However, highly resistant populations of beetles occur which cannot be well controlled even with more frequent applications, and foliar applications do not provide control of damage that occurs during seedling emergence, which is important in parts of the mid-Atlantic region.

Flea Beetles: Aldicarb is highly effective for control of flea beetles. However, performance of aldicarb does not differ substantially from that of phorate, disulfoton, or several other granular systemic insecticides or from many foliar treatments.

Leafhoppers: Aldicarb is highly effective for providing early season control of leafhoppers on potato. However, it is no more effective than are phorate, disulfoton and several other granular systemic insecticides or from many foliar treatments.

Aphids: Green peach aphid is a very difficult insect to control. Highly resistant populations have developed in many areas of the country. There is widespread concern about insecticide-resistant green peach aphid on a wide variety of vegetable, field, and greenhouse crops. Aldicarb is the most effective granular systemic insecticide, often providing 1 to 1½ months of control.

Sidedressed, post-emergence applications can give effective season-long control in some areas such as Colorado (L. West, West Consulting Company, personal communication). Alternative granular treatments such as phorate and disulfoton lose effectiveness in mid-season and often have very high aphid populations during late season without supplemental controls. Several foliar insecticides are labelled for control of green peach aphid, with variable effectiveness. Resistance has developed to all foliar treatments, except methamidophos in at least one growing area. Methamidophos remains the primary alternative treatment, and in many areas the only foliar treatment, for green peach aphid.

Stubby Root Nematodes/Corky Ringspot: Aldicarb is the only effective treatment for reducing losses by corky ringspot transmitted by stubby root nematodes. Because the nematodes often occur deep within the soil, moving episodically to the plant root zone, fumigants fail to adequately penetrate and provide control. Alternative granular or liquid nematicides (ethoprop, oxamyl, carbofuran) provide levels of control that are 80 percent poorer than aldicarb (Pete Weingartner, University of Florida, personal communication).

Root Lesion Nematodes/Early Dying: Lesion nematodes are relatively easy to control with the more volatile nematicides. Under low pest pressure, non-volatile nematicides such as aldicarb, oxamyl, carbofuran, and ethoprop can provide adequate control. However, these alternative nematicides are not as effective where higher pest populations occur. In addition, effective use of ethoprop involves application techniques that are not possible with existing commercial equipment (George Bird, Michigan State University, personal communication). Under conditions of high pest pressure, fumigants such as metam-sodium or 1,3-dichloropropene are used. For example, treatment with metamsodium in Michigan has increased yields of the susceptible cultivar 'Superior' by 450 cwt; less susceptible cultivars often get a 60 cwt or more increase in yield (George Bird, Michigan State University, personal communication). A major limitation of fumigation is the high cost which is in excess of $200/acre.

Root-Knot Nematodes: Aldicarb has been effective and is widely used to control southern root-knot nematode (*M. incognita*) and northern root-knot nematode (*M. hapla*). However, in heavily infested areas in the South, such as southern Alabama, potato can be seriously damaged late in the growing season even with aldicarb (or 1,3-dichloropropene) treatment. Columbia Basin root-knot nematode has not been well controlled with aldicarb. In infested fields, fumigation is required for control. Aldicarb is often used in addition to fumigation to give additional control.

Safety Factors

Drift: Use of aldicarb as a planting time or sidedress treatment can typically substitute for 3 or more early-season foliar applications, particularly in areas of severe Colorado potato beetle problems. Concurrently, this avoids problems associated with drift from foliar applications. Problems with drift are particularly acute in the mid-Atlantic and New England potato production areas. In these regions, expanding development has brought housing and even schools in close proximity to much of the potato growing acreage. This has increased potential for conflict between growers and the public. This problem is particularly severe where foliar applications are considered a form of air-borne pollution. Foliar applications may be restricted in certain acres due to hazard of drift.

Applicator Exposure: Technical aldicarb is the most acutely toxic insecticide/nematicide marketed in the United States. However, the 15 percent granular formulation likely poses less applicator hazard than most alternatives. Foliar applications involve liquids, usually emulsifiable concentrates, or powders diluted in water for application. It is widely recognized that pesticides in liquid can result in greater pesticide exposure during application than granules. Exposure is particularly likely during mixing of concentrated liquid formulations (which can splash) or powders (which can be inhaled) because the toxicity of essentially all aldicarb alternatives are similarly classified as Class I poisons, they can result in increased applicator exposure hazard. Since exposure is also related to application frequency, aldicarb has an advantage in reducing the number of applications required during the season.

Potential for Pest Resistance

The value of aldicarb for managing insecticide resistance of potato pests was repeatedly stressed by many potato specialists. Concerns with resistance in the Colorado potato beetle were most frequently raised, particularly by workers in the Northeast and Midwest. Green peach aphid resistance to insecticides was mentioned by some seed certification personnel.

Colorado potato beetle has not developed resistance to aldicarb as quickly as for other insecticides. In New Jersey, Colorado potato beetle populations demonstrated approximately 500-fold resistance to carbofuran, but only 6-fold resistance to aldicarb (Forgash, 1981). This study indicated that repeated exposure to aldicarb did not significantly increase the levels of resistance in Colorado potato beetle and that there was minimal cross resistance to other carbamate insecticides. A primary factor in the slow rates of aldicarb resistance development by Colorado potato beetle is that systemic activity is lost relatively early in the growing season. Toxicity of aldicarb is directed mainly against overwintered adults and first generation larvae, before any induction of general detoxification enzymes from exposure to potato alkaloids or other toxins. Therefore, these particular life stages are exposed to aldicarb when their tolerance is lowest (White and Grafius, 1988). Later generation adults and larvae are largely unaffected by aldicarb because concentration in the plant decreases with time. Therefore, overall selection pressure for insecticide resistant Colorado potato beetle populations each year is relatively low (Forgash, 1981). However, there are some reports that Colorado potato beetle tolerance to aldicarb may be increasing in some areas (Forgash, 1985; Johnson and Sandvol, 1986).

Availability of aldicarb will reduce usage of other insecticides. Therefore, selection pressure for Colorado potato beetle insecticide resistance to these materials will be reduced. Retention of aldicarb on the list of available insecticides will likely prolong the effective life of all available materials. It is estimated that the addition of a single noncross-resistant insecticide (like aldicarb) to a program where only one other insecticide is available would at least double the effective length of chemical control for Colorado potato beetle (White and Grafius, 1988). The availability of aldicarb is also important for Colorado potato beetle resistance management programs using new, environmentally safe, biological insecticides. Commercial formulations of newly discovered strains of the bacteria *Bacillus thuringiensis* recently have been approved for use against Colorado potato beetle in potato. Unfortunately, these bacterial toxins are only effective against Colorado potato beetle larvae. Recent studies in Massachusetts with insecticide-resistant Colorado potato beetle populations demonstrated that aldicarb applied at one-third the recommended rate at hilling, followed by applications of the bacterial formulation, provided excellent season-long control of Colorado potato beetle (Ferro and Gelernter, 1988). Aldicarb suppressed the overwintered adult population and the bacterial treatments controlled later infestations of larvae. Similar management

programs adopted by potato growers would decrease insecticide resistance problems with Colorado potato beetle (and reduce pesticide contamination of the environment) because repeated foliar applications of other insecticides are not needed.

Although aldicarb is widely perceived to have substantial value in managing problems with insecticide resistance, attempts to quantify this value are extremely difficult. The outstanding single effort made in this area was done by White and Grafius (1988). This study was based on an extensive analysis of impacts from both aldicarb use and the absence of aldicarb following banning on Long Island. The assessment indicated a potential annual value of $16.7 million in the Northeast, $7.4 million in the North-Central, and $7.3 million in Western potato producing states. Many of the basic assumptions and figures of White and Grafius (1988) are accepted by the Aldicarb Benefits Assessment Committee. Some figures should be modified to reflect the reduced acreage of current aldicarb use due to regulatory restrictions in such states as Wisconsin, New York, Massachusetts, and Connecticut. In addition, the indicated costs of alternative treatments are somewhat high since they are based on treatment costs during years of an abrupt transition of treatments, including widespread use of oxamyl, a very expensive alternative. Another concern with the White and Grafius (1988) study is that much of the aldicarb benefit was based on figures of decreased yield following the elimination of aldicarb use in Long Island. In the study, the yield benefits were ascribed to Colorado potato beetle management. However, nematode control and other pest problems were also controlled by aldicarb and it is not clear whether the reduced yields on Long Island are primarily related to reduced Colorado potato beetle control.

Specific economic benefits of resistance management cannot be calculated since adequate data are not available to calculate the value of resistance management that aldicarb provides. However, aldicarb has high value in resistance management, particularly for control of Colorado potato beetle in the Middle Atlantic and Midwest states and for control of green peach aphid in seed potato production.

The development of leafhopper resistance to aldicarb has not been a problem since infestations are initiated by annual flights of susceptible individuals from the South.

Green peach aphid is among the most difficult insects to control with insecticides. Resistance levels are very high in many populations and some populations in greenhouses can only be consistently controlled with aldicarb. Resistance of green peach aphid to aldicarb has not been reported. Green peach aphid resistance to other insecticides has increased in recent years, and severe resistance has been reported in several seed production areas of the United States, including Colorado and Minnesota. Resistance problems are likely to increase steadily in the future, particularly since extremely resistant populations are widespread in greenhouse crops.

Table 19. United States potato production and estimated aldicarb usage

State	Acreage, 1984-86 (x 1000)	Average crop value, 1984-86	Estimated aldicarb use, 1988 (acres)
Alabama	12.33	$11,600,000	4,111 (33%)
Arizona	5.53	$12,030,000	4,980 (90%)
California	53.67	$180,900,000	4,254
Colorado	64.53	$66,667,00	750[1]
Connecticut	0.93	$1,400,000	186
Delaware	7.13	$9,500,000	3,780 (53%)
Florida	34.53	$70,600,000	30,000 (86.9%)
Idaho	329.67	$322,266,000	131,866 (40%)
Illinois	2.90	$3,500,000	-0-
Indiana	4.67	$5,200,000	-0-
Iowa	1.67	$1,200,000	-0-
Maine	90.33	$87,400,000	12,500[1]
Maryland	1.90	$2,400,000	1,007 (53%)
Massachusetts	3.00	$3,333,000	-0-
Michigan	47.63	$64,800,000	23,816 (50%)
Minnesota	76.37	$58,400,000	3,387[1]
Montana	7.53	$12,600,000	6,780[1]
Nebraska	9.83	$12,300,000	-0-
Nevada	8.67	$10,900,000	8,667 (100%)
New Hampshire	0.20	$312,550	17 (>9%)
New Jersey	8.10	$11,100,000	3,078 (38%)
New Mexico	9.80	$14,100,000	1,715 (17.5%)
New York	34.07	$47,900,000	-0-
North Carolina	16.10	$13,400,000	805 (5%)
North Dakota	128.00	$72,000,000	-0-
Ohio	9.97	$13,600,000	6,279 (63%)
Oregon	56.00	$89,700,000	22,600 (60%)
Pennsylvania	21.67	$28,600,000	17,334 (80%)
Rhode Island	1.87	$2,600,000	-0-
South Dakota	11.67	$7,000,000	-0-
Tennessee	2.30	$2,200,000	-0-
Texas	17.43	$32,900,000	1,307 (7.5%)

Table 19. United States potato production and estimated aldicarb usage

State	Acreage, 1984-86 (x 1000)	Average crop value, 1984-86	Estimated aldicarb use, 1988 (acres)
Utah	6.40	$7,100,000	640 (10%)
Vermont	0.15	$200,000	100 (66%)
Virginia	14.83	$14,200,000	6,200 (42%)
Washington	122.67	$239,700,000	61,334 (50%)
West Virginia	4.00	$5,000,000	-0-
Wisconsin	61.50	$84,100,000	-0-
Wyoming	1.80	$2,000,000	-0-
Total	1291.35	$1,624,708,550	357,493

[1] Primary or exclusive use is on seed potato. Benefit analysis on seed potato use considered in Tables 10-12.

Table 20. Potato producing states that will not be included in benefit assessment for commercial potato	
State	Reason for excluding in analysis
Alaska	No use
Connecticut	Use negligible, declining
Illinois	No use
Indiana	No use
Iowa	No use
Maine	Use limited to seed acreage[1]
Massachusetts	Use negligible, declining
Minnesota	Use limited to seed acreage
Montana	Use limited to seed acreage
Nebraska	Use negligible, limited to seed acreage
New Hampshire	Use negligible, declining
New York	Use of aldicarb prohibited
North Dakota	Use negligible, limited to seed acreage
Rhode Island	Use of aldicarb prohibited
South Dakota	No use
Tennessee	No use
Utah	Negligible use of questionable benefit
Vermont	Use negligible, declining
West Virginia	No use
Wisconsin	Use of aldicarb prohibited
Wyoming	No use

[1]Seed potato benefits considered separately

Table 21. Estimated current use of aldicarb on commercial potato, 1988

State	Estimated aldicarb use (acres)	Target pests
Alabama	4,111	Southern root knot-nematode
Arizona	4,980	Potato psyllid, western potato leafhopper, flea beetles
California	4,162	Aphids/leafroll
Colorado	200	Stubby root nematode/Corky ringspot
Delaware	3,780	Colorado potato beetle
Florida	30,000	Stubby root nematodes/corky ringspot
Idaho	31,866	Nematodes/early dying, Colorado potato beetle, aphids/leafroll,northern root-knot nematode
Maine	1,250	Colorado potato beetle
Maryland	1,007	Colorado potato beetle
Michigan	23,816	Sting nematodes/early dying,Colorado potato beetle
Nevada	8,667	Nematodes/early dying, Colorado potato beetle, aphids/leafroll
New Jersey	3,078	Colorado potato beetle
New Mexico	1,715	Thrips, wireworms
North Carolina	805	Colorado potato beetle
Ohio	6,279	Colorado potato beetle, sting nematodes/early dying
Oregon	22,600	Nematodes/early dying,aphids/leafroll
Pennsylvania	17,334	Colorado potato beetle, sting nematodes/early dying
Texas	1,307	Aphids, leafhoppers, psyllids, flea beetles
Virginia	6,200	Colorado potato beetle
Washington	61,334	Nematodes/early dying, aphids/leafroll, Colorado potato beetle

Table 22. Summary of aldicarb alternatives and estimated yield differential compared to aldicarb

State	Aldicarb alternative	Yield differential alternatives and comments
Alabama	1,3-dichloropropene	Equivalent yield, not all acreage is suitable for fumigation alternative. No alternative on approximately 1/3 of the acreage, which would be lost to production.
Arizona	disulfoton,phorate, foliar sprays	No apparent yield advantage. Equivalent alternatives.
California	disulfoton, phorate, foliar methamidophos	No apparent quality advantage. Equivalent alternatives.
Colorado	No alternative	Platteville area (200 acres) infested with corky ringspot/stubby root nematode will be abandoned.
Delaware	Multiple foliar applications	10% yield loss.
Florida	No alternative	Hastings area would be lost to production (28,000 acres).
Idaho	disulfoton, phorate, foliar sprays (includes ethamidophos)	5% yield loss estimated despite alternatives.
Maryland	Multiple foliar applications	10% yield loss.
Michigan	Multiple foliar applications, fumigation with 1,3-dichloropropene, metam-sodium	10% yield loss.
Nevada	disulfoton, foliar applications, fumigation	5% yield loss possible
New Jersey	Multiple foliar applications	10% yield loss
New Mexico	disulfoton, phorate, foliar applications	No yield loss.
North Carolina	Multiple foliar applications	5% yield loss
Ohio	Multiple foliar applications	10% yield loss
Oregon	disulfoton, phorate, fumigation, multiple foliar applications	5% yield loss
Pennsylvania	Multiple foliar applications	10% yield loss. Requirement for increased foliar applications would likely cause Lancaster, Lehigh, York County production area to be abandoned (50% of state acreage, approximately 10,833 acres).
Texas	Disulfoton, phorate, foliar applications	Equivalent alternatives
Virginia	Multiple foliar applications	10% yield loss.
Washington	Disulfoton, phorate, foliar applications, fumigation	5% yield loss.

Table 23. Costs of pesticides used in calculation of aldicarb and aldicarb alternative pest management practices on potato[1]

Pesticide	Cost ($ lb ai)[1]	Comments
Temik 15G	15.87	Planting time treatment
Thimet 20G	6.15	Planting time treatment
DiSyston 15G	6.00	Planting time treatment
Monitor 2WM	12.06	$4.00 application cost
Asana XL	135.15	" " "
Furadan 4F	10.37	" " "
Imidan	5.70	" " "
Pounce 3.2E	32.81	" " "
Vydate 2L	19.59	" " "
Telone II	8.03/gal	$12.50 application cost

[1] Based on April 13, 1989, average prices in AGCHEMPRICE (Ben Mason, El Paso, Texas).

Table 24. Value of commercial potato currently treated with aldicarb and crop value where alternatives are used

State	Value ($) of crop treated with aldicarb	Value ($) of crop treated with alternatives	Alternative difference in yield %	Value($) of crop loss with alternative
Alabama	3,866,667	2,577,774 1,288,889	-0- 100[1]	-0- 1,288,889
Arizona	10,827,000	10,827,000	-0-	-0-
California	14,170,783	14,170,783	-0-	-0-
Colorado	206,620	206,620	100[1]	206,602
Delaware	5,035,000	5,035,000	10	503,500
Florida	61,337,964	57,248,764 4,089,200	100 -0-	57,248,764 -0-
Idaho	128,906,667	128,906,667	5	6,455,333
Maryland	1,272,000	1,272,000	10	127,200
Michigan	32,400,000	32,400,000	10	3.240,000
Nevada	10,900,000	10,900,000	-0-	-0-
New Jersey	4,218,000	4,128,000	10	-0-
New Mexico	1,057,500	1,057,000	-0-	-0-
North Carolina	670,000	670,000	5	33,500
Ohio	8,568,000	8,568,000	10	856,800
Oregon	53,820,000	53,820,000	5	2,691,000
Pennsylvania	22,880,000	8,580,000 11,440,000	10 100	858,000 11,440,000
Texas	2,467,500	2,467,500	-0-	-0-
Virginia	5,935,414	5,935,414	-0-	593,541
Washington	119,850,000	119,850,000	5	5,992,500

[1]100% loss involved where no alternative exists and aldicarb-treated acreage will be abandoned.

Table 25. Summary of potato acreage likely to be abandoned in the absence of aldicarb and crop value			
State	Acreage	Crop value	Reason for abandoned acreage
Alabama	1,370	1,288,889	Inability to use fumigation alternative for root-knot nematode control
Colorado	200	206,620	Inability to adequately control corky ringspot in Platteville area with alternative
Florida	28,000	57,248,764	Inability to adequately control corky ringspot in Homestead area with alternative
Pennsylvania	10,833	11,440,000	Inability to economically produce potato in Montgomery and Humboldt County areas (approximately 50% of state acreage) due to inadequate Colorado potato beetle control and limitations on foliar applications

Table 26. Cost differential associated with aldicarb alternatives and net value on commercial potato. Aldicarb application estimated at $47.61/acre based on 3 lb ai 15G

State	Cost/acre differential of alternative ($)	Acreage treated with alternative[1]	Value of aldicarb compared to alternative ($)
Alabama	-2.99[2]	2,741	8,195
Arizona	-8.30[3]	4,980	41,334
California	-3.52[4]	4,162	14,650
Delaware	-11.66[5]	3,780	44,075
Florida	-2.99[2]	2,000	5,980
Idaho	-3.52[4]	131,867	464,171
Maryland	-11.66[5]	1,007	11,742
Michigan	-11.66[5]	23,816	277,695
Nevada	-3.52[4]	8,667	30,508
New Jersey	-11.66[5]	3,078	35,889
New Mexico	-8.30[3]	1,715	14,235
North Carolina	-11.66[5]	805	9,386
Ohio	-11.66[5]	6,279	73,213
Oregon	-3.52[4]	22,600	79,522
Pennsylvania	-11.66[5]	6,501	75,802
Texas	-8.30[3]	1,307	10,848
Virginia	-11.66[5]	6,200	72,292
Washington	-3.52[4]	61,334	215,896
Total		292,839	1,485,581

[1]Current aldicarb acreage (Table 19) - acreage that would be abandoned due to inadequate alternative (Table 25).
[2]Estimated cost of 4 gallons of Telone II plus application cost ($44.62/acre).
[3]Estimated cost of planting time treatment of DiSyston 15G, plus a single foliar application of Asana and Pounce ($39.31/acre).
[4]Estimated cost of planting time treatment of DiSyston 15G plus 2 additional foliar applications of Monitor ($44.09/acre).
[5]Average of 3 additional foliar applications at an average cost of $7.98 (chemical) plus $4.00 (application) ($35.95/acre). Average cost of chemical based on average cost of Pounce, Asana, Thiodan, and Vydate.

Table 27. Net loss to production in absence of aldicarb and use of alternative

State	Loss ($) in crop value[1]	Change ($) in treatment cost[2]	Aldicarb net ($) value to state
Alabama	1,288,889	-8,195	1,280,694
Arizona	-0-	-41,334	-41,334
California	-0-	-14,798	-14,798
Colorado	206,620	-0-	206,620
Delaware	503,500	-44,075	459,425
Florida	57,248,764	-5,980	57,242,784
Idaho	6,445,333	-464,171	5,981,162
Maryland	127,200	-11,742	115,458
Michigan	3,240,000	-277,695	2,962,305
Nevada	-0-	-30,508	-30,508
New Jersey	412,800	-35,889	376,911
New Mexico	-0-	-14,235	-14,235
North Carolina	33,500	-9,386	24,114
Ohio	856,800	-73,213	783,587
Oregon	2,691,000	-79,522	2,611,478
Pennsylvania	12,229,800	-75,802	12,153,998
Texas	-0-	-10,848	-10,848
Virginia	593,541	-72,292	521,249
Washington	5,992,500	-215,896	5,776,604
Total	91,870,247	1,485,581	90,384,666

[1] From Table 24.
[2] From Table 26.

Table 28. Seed potato acreage entered for certification and certified, 1985-86[1]

State	Acres entered	Acres certified	Percent certified
California	1,850	1,773	95.8
Colorado	13,055	10,871	83.3
Idaho	52,020	50,706	97.5
Maine	30,666	27,814	90.7
Michigan	4,609	4,320	93.7
Minnesota	23,677	22,883	96.6
Montana	7,529	7,529	100.0
Nebraska	5,751	5,330	92.3
New York	1,915	1,890	98.7
North Dakota	32,288	31,016	96.1
Oregon	4,888	4,599	94.1
Pennsylvania	438	438	100.0
South Dakota	1,306	1,286	98.5
Utah	309	240	77.6
Washington	2,063	2,063	100.0
Wisconsin	10,999	10,588	96.3
Wyoming	254	161	63.3

[1] Source: 1987 Potato Statistical Yearbook and 1988 Potato Statistical Yearbook.

Table 29. Estimated aldicarb use[1] on seed potato in 1988 and estimated acreage loss of certification associated with loss of aldicarb on seed potato

State	Area treated with aldicarb		Estimated pest pressure	Potential for loss aldicarb loss[2]
	Acres	Percent		
California	> 92	(>5%)	L-M	5
Colorado	> 652	(>5%)	L-M	33
Idaho	> 5,202	(>10%)	Light	104
Maine	12,250		Moderate	980
Michigan	3,457	(75%)	Moderate	277
Minnesota	> 3,551	(>15%)	Light	71
Montana	7,153	(95%)	L-M	358
Nebraska	-0-		Light	-0-
New York	-0-		Moderate	-0-
North Dakota	> 646	(>2%)	Light	13
Oregon	3,128[3]		L-M	156
Pennsylvania	438	(100%)	Moderate	35
South Dakota	-0-		Light	-0-
Utah	309	(100%)	Moderate	25
Washington	> 206	(>10%)	L-M	10
Wisconsin	-0-		Moderate	-0-
Wyoming	-0-		L-M	-0-

[1] Total seed acreage based on 1985-1986 average entered for certification. Current treated acreage based on actual use figures (Maine) or on estimated percentage treated in 1988.
[2] Estimated increase in certification rejection on current acreage treated with aldicarb is set at 8% for areas of moderate pest pressure (Maine, Pennsylvania, Michigan, Utah); 5% for areas of light-moderate pest pressure (California, Colorado, Montana, Oregon, Washington); and 2% for areas of light pest pressure (Idaho, Minnesota, North Dakota). States with no aldicarb use on seed potato (New York, Wisconsin, South Dakota, Nebraska) are not considered in the aldicarb benefits analysis for seed potato.
[3] Approximately 90% of the Oregon acreage is treated in the Northeast and Central areas; 25% in the Klamath Valley.

Table 30. Estimated loss in seed potato production and value from loss of aldicarb

State	Average yield (cwt)[1]	Estimated seed yield (cwt)[2]	Lost seed potato yield (cwt)[3]	Lost seed potato value ($)[4]
California	398	358	1,790	6,265
Colorado	325	293	9,669	33,842
Idaho	290	262	27,248	95,368
Maine	275	248	243,040	850,640
Michigan	273	246	68,142	238,497
Minnesota	210	189	13,419	46,967
Montana	287	287[5]	102,746	359,611
North Dakota	178	160	2,080	7,280
Oregon	465	419	65,364	228,774
Pennsylvania	240	216	8,208	28,728
Utah	257	231	5,775	20,213
Washington	523	471	4,710	16,485
Total			552,191	1,932,670

[1] Based on average state yields (1985-1987). Source: 1988 Potato Statistical Yearbook.)
[2] Seed yields are estimated at 90% of table stock/processing potato production.
[3] Average yield of seed potato x estimated increased acres losing certification due to aldicarb loss (Table 29).
[4] Seed potato is estimated to be worth an average of $3.50/cwt more than table stock/processing potato.
[5] Montana acreage is almost entirely seed potato so average state yields are considered equivalent to seed potato yields.

Table 31. Summary of aldicarb use benefits on commercial and seed potato in the United States

State	New value to table stock/ processing[1]	Value to seed potato production[2]	Value to insecticide resistance management[3]	Total value[4]
Alabama	1,280,694	-0-	N	1,280,694
Arizona	-41,334	-0-	N	-41,334
California	-14,798	6,265	L	-8,533
Colorado	206,620	33,842	L	240,462
Delaware	459,425	-0-	H	459,425
Florida	57,242,784	-0-	N	57,242,784
Idaho	5,981,162	95,368	L	6,076,530
Maine	-0-	850,640	M-H	850,640
Maryland	115,458	-0-	H	115,458
Michigan	2,962,305	238,497	M	3,200,802
Minnesota	-0-	46,967	L	46,967
Montana	-0-	359,611	L	359,611
Nevada	30,508	-0-	N	-30,508
New Jersey	376,911	-0-	H	376,911
New Mexico	-14,235	-0-	N	-14,235
North Carolina	24,114	-0-	M	24,114
North Dakota	-0-	7,280	L	7,280
Ohio	783,587	-0-	M-H	783,587
Oregon	2,611,478	228,774	N	2,840,252
Pennsylvania	12,153,998	28,728	H	12,182,726
Texas	-10,848	-0-	N	-10,848
Utah	-0-	20,213	N	20,213
Virginia	521,249	-0-	H	521,249
Washington	5,776,604	16,485	N	5,793,089
Total	90,384,666	1,932,670		92,317,336

[1] From Table 9.
[2] From Table 12.
[3] Discussed in this chapter and in state reports.

Aldicarb Use on Sugarbeet

Vernon E. Burton and Saad Hafez

Production of sugarbeet averaged 20.3 million tons annually from 1985-87. Crop value during that period averaged $921.5 million (Source: Beet Sugar Research Foundation, Ft. Collins, Colorado). Leading states in production are Minnesota, California, North Dakota, and Michigan. Since sugarbeet is processed within each producing region, there is considerable value added locally from the sugarbeet industry. In Wyoming, the sugarbeet industry provided 1,154 factory jobs (payroll $10.3 million) in 1986, providing 6 percent of the non-farm jobs in the three counties where processing factories were located. This factory employment is often considered essential to the economic health of the rural communities in which they are located. Sugarbeet production is also labor intensive and requires considerable amounts of seasonal labor.

Registration Summary

Aldicarb is labelled for control of nematodes, sugarbeet root maggot, aphids, leafminers, and leafhoppers. It has been registered for use on sugarbeet since the early 1970's and was rapidly adopted by many producers, particularly after the development of sugarbeet root maggot strains resistant to chlorinated hydrocarbons. Applications are made at planting.

1,3-dichloropropene is applied as a pre-plant treatment requiring a minimum of 7 to 14 days exposure for effectiveness. In addition an aeration period of 1 or more weeks per 10 gallons (Telone II) applied per acre is required; the aeration period is longer if soil temperatures are cool or heavy rains occur after application. Because of the pre-planting requirements, most applications are made in the fall.

Pest Infestation and Damage

Essentially all applications of aldicarb in the United States are made for control of nematodes and sugarbeet root maggot two pests, except in California. A summary of sugarbeet pests and the use of their aldicarb for control follows.

Sugarbeet Cyst Nematode: The sugarbeet cyst nematode, *Heterodera schachtii* Schmidt, is the key sugarbeet pest in most production areas of the United States. The nematode feeds upon the roots of the plant, disrupting normal root development. Damaged sugarbeet plants produce numerous rootlets and beet yields can be substantially reduced. Sugarbeet cyst nematode injury also can greatly reduce sugar content of roots. Total crop loss is possible during heavy infestations. Sugarbeet cyst nematode is an introduced pest, but has become spread widely through contaminated soil and machinery. Currently more than 50 percent of sugarbeet acreage is infested throughout sugarbeet production regions of the United States. Within fields, original areas of infestation may be spotty but gradually become more uniform with time. Large areas of sugarbeet acreage has been abandoned because of infestation by sugarbeet cyst nematode.

Sugarbeet Root Maggot: The sugarbeet root maggot, *Tetanops myopaeformis* (Roder), feeds on the roots of developing beets. Seedling beets can be killed by this injury. Older beets are deformed and may yield poorly. In North Dakota, 50 percent yield reductions typically occur from maggot infestations in the absence of controls (Albin Anderson, North Dakota State University, personal communication, 1989). Sugarbeet root maggot occurs throughout the upper Midwest and Rocky Mountain regions of the United States. Infestations have decreased throughout the Rocky Mountain region in the past decades to the point where little acreage is regularly infested at economically damaging levels. The cause of this decline in pest severity is unknown, but it may in part be related to aldicarb use. Essentially all economically damaging populations of sugarbeet root maggot are found in the Red River Valley production region of North Dakota and Minnesota. The area around Worland, Wyoming also is regularly infested, but control is achieved in that region as an incidental benefit of sugarbeet cyst nematode treatment with aldicarb. Extreme populations of sugarbeet root maggot are most often limited to areas with lighter soils, in particular the northern Red River Valley production area of North Dakota. Researchers at North Dakota State University are able to predict the severity of infestations so that treatments are focused on those areas.

Leafhoppers: Several species of leafhoppers may colonize sugarbeet. Historically, the most important pest was the beet leafhopper, *Eutettix tenellus* Baker, a vector of sugarbeet curly top disease. This virus disease is limited to the low rainfall areas of the Western United States. Although both curly top and the beet leafhopper occur throughout the western region, it is a serious pest in Wyoming, Texas and California. The most severe problems occur in the Bighorn Basin area of Wyoming. Problems in California are limited to the west side of the Central Valley and have been very sporadic in occurrence. Recently, the incidence of the disease in California has been minor and essentially no treatments are applied solely for control of the disease. In California, recent problems with the southern garden leafhopper, *Empoasca solana* DeLong, have occurred. The insect is not a vector of disease but injures plants directly by feeding wounds. Studies conducted by Frate and Burton (Vernon Burton, personal communication, 1989) indicate that populations exceeding 10 leafhoppers per leaf reduce yield. Aldicarb effectively controls this insect.

Aphids: Aphids are primarily important as vectors of virus disease. The green peach aphid, *Myzus persicae* (Sulzer), is often the most serious disease vector; in California, bean or cowpea aphids (*Aphis* spp.) are also important. Beet yellows, beet western yellows, and beet mosaic are among the diseases spread to sugarbeet by aphids. Bean aphids may also directly affect yields when they occur in large numbers on plants. In California, populations occasionally occur at levels that destroy foliage. Sugarbeet yield is reduced 25 to 30 percent when 50 percent of the foliage is destroyed (C.G. Summers, University of California at Berkeley, personal communication, 1989).

Pest Management

Sugarbeet Cyst Nematode: Aldicarb is generally considered to be the only granular (non-fumigant) nematicide that can consistently control sugarbeet cyst nematode. Almost all current use of aldicarb on sugarbeet is in the Western states (Idaho, California, Nebraska, Wyoming, Montana, Colorado, and Oregon). It is most often used as a planting-time treatment at a rate of 14-27 lb of the 15G formulation. Split applications are also registered, allowing a total of up to 6 pounds active ingredient (lb ai) of aldicarb to be applied to the crop during a growing season. The latter treaments are most widely used in the northwestern production area of Oregon and Idaho. Because of its water solubility, aldicarb is readily moved within the root system to provide effective

coverage. Control may be somewhat reduced during very dry conditions, but this is only a factor on the small area that is not irrigated.

A benefit assessment by Rhone-Poulenc summarized 142 field trials and reported an average of 3.5 ton per acre (24.6 percent) increase in yield compared to an untreated check. The few published university trials indicate that this may be accurate for heavily infested acreage. However, sugar company trials in Colorado, which accounted for 49 of the Rhone-Poulenc reported trials, were in the 2 to 3 ton per acre range (Mok Yun, Mono-Hy Hybrids, personal communication, 1989). Also, 41 of the reported trials were from Utah, which is no longer a producing state. In subsequent economic analyses, the figure of 3.5 tons/acre yield benefit will generally be used where local data is not available. Where local data on yield benefits exists, and is supplied by University researchers, sugarbeet company personnel, or Rhone Poulenc (Colorado, California, Idaho, Michigan) the local data will be used.

Terbufos and carbofuran are labelled for control or suppression of sugarbeet cyst nematode. Neither of these treatments was considered to be nearly as effective as aldicarb and performance is more erratic. These materials are not used by producers to any appreciable extent as a control for sugarbeet cyst nematode. They are not considered to be adequate alternatives. Furthermore, future availability of granular carbofuran is questionable.

The fumigant 1,3-dichloropropene is highly effective for control of sugarbeet cyst nematode. The benefit assessment by Rhone Poulenc indicates that yield increases with 1,3-dichloropropene exceed aldicarb by 3.6 tons/acre. In the Rocky Mountain region, sugar company trials suggest that the yield response from 1,3-dichloropropene is in the 5 to 6 ton per acre range, compared to 2 to 3 tons per acre for aldicarb (Mok Yun, Mono-Hy Hybrids, personal communication). Data from Idaho suggest an even greater response from fumigation treatment (Saad Hafez, University of Idaho, personal communication). For the purpose of this analysis, a 3 ton per acre benefit increase for 1,3-dichloropropene relative to aldicarb will be used. Where recent state University data has been published, such as for the Idaho-Oregon producing region, these yield data will be used in benefits analyses. Despite the substantial well-known yield advantages associated with 1,3-dichloropropene, it has received little use by producers. In part, this is due to difficulties in handling fumigants with which most producers are inexperienced. 1,3-dichloropropene is a highly hazardous liquid which would generally require custom application and special equipment. Effectiveness of 1,3-dichloropropene also requires favorable soil conditions. Fumigation effects can be greatly diminished in soils that are too dry. Since fall applications in the arid, irrigated acreages of the West often do not have access to water in the fall, soil moisture conditions can be variable during the application period. Finally, financial considerations limit adoption of 1,3-dichloropropene by many sugarbeet producers. Expense is high, up to double that of aldicarb. Perhaps more important, applications must usually be made in fall, sometimes before the next season acreage has been determined. This added economic risk is perceived as a major limitation.

Crop rotation can control sugarbeet cyst nematode since the host range of the nematode is fairly restricted, being limited to crops and weeds in the beet and brassica families. However, because eggs are highly persistent in the soil, a 4-year rotation years is needed. Crop rotation has been used successfully in Michigan, where a minimum 4-year rotation is required as part of production contracts; 6-year rotations are required on land that is known to be infested. This rigorous rotation requirement has essentially eliminated the need for supplemental treatments in Michigan. Suitable alternative crops and adequate land have favored the adoption of this practice. However, crop rotation is not widely practiced in the Rocky Mountain region, where land suitable for production

is not plentiful. Alternative crops are also less available and sugarbeet is often the highest value cash crop. As a result, rotations of only 2 to 3 years are possible.

Sugarbeet Root Maggot: Tests at North Dakota State University (1983-86) show an average yield increase of 4.85 tons per acre attributable to aldicarb treatment (Albin Anderson, personal communication, 1989). In North Dakota, aldicarb is considered to be a superior treatment in fields with high pest pressure. This was demonstrated in two North Dakota State University trials in 1975, when aldicarb increased yields over the untreated check by an average of 6.6 tons per acre. Aldicarb treated sugarbeet had 1 ton per acre higher yields than terbufos, the next best insecticide treatment. Producers estimated that aldicarb added $299.09 per acre in crop value to heavily infested commercial fields in 1986 (Albin Anderson, personal communication, 1989).

Several granular insecticides have been labelled for control of sugarbeet root maggot, including terbufos, carbofuran, chlorpyrifos, phorate, and fonofos. All of these insecticides are substantially cheaper to apply than aldicarb and have the dominant share of the market where sugarbeet root maggot is the key pest of the crop. Carbofuran is generally not considered to be an alternative. In the Red River Valley, recent performance has been erratic and it is no longer recommended for control. Future availability of granular carbofuran as an alternative may also be limited due to regulatory restrictions related to avian hazard. Comparison of aldicarb with the alternative treatments in comparable North Dakota State University trials (Albin Anderson, unpublished data) for the years 1983-87 indicated yield increases of 1.88 and 0.16 tons per acre attributable to aldicarb compared with chlorpyrifos and terbufos, respectively. Trials in commercial fields during 1986, monitored by North Dakota State University, indicated the following crop values of test plots: aldicarb, $565.50 per acre; chlorpyrifos, $454.50 per acre; terbufos, $437.03 per acre; untreated check, $266.41 per acre. Data presented by Rhone Poulenc showed yield increases of 0.9 tons per acre using aldicarb compared to treatments with both Terbufos and Chlorpyrifos. It is presumed that trials were generally conducted in highly infested fields. These data are variable and difficult to interpret. For the purpose of this analysis, the yield benefits of aldicarb in heavily infested areas in the Red River Valley of North Dakota and Minnesota (the principal area of aldicarb use for sugarbeet root maggot control) will be set at the Rhone-Poulenc level of 0.9 tons/acre. On less infested acreages, alternative insecticides will be considered equally effective. Since these products cost less and are the main insecticides currently used by producers, no potential economic benefit from aldicarb will be considered to exist on acreage not currently treated with aldicarb.

Sugarbeet root maggot has a history of developing resistance to chlorinated hydrocarbon insecticides. Aldicarb has been used in North Dakota for over a decade and resistance development has not been observed. There is some value to aldicarb in resistance management since it is the only non-organophosphate currently used.

Leafhoppers: Rhone Poulenc data (1970-84) indicate an average of 4.5 tons per acre increase when leafhopper/curly top is controlled compared to the untreated check. Data on effectiveness of chemical alternatives are unavailable, but adequate alternatives are assumed to exist. However, currently there is little use of aldicarb solely for curly top control.

Some curly top resistant cultivars are available. Their use is mandated in the Bighorn Basin area of Wyoming and they are widely planted.

Aphids: Aldicarb and carbofuran are superior treatments for control of aphids and the incidence of beet yellows disease in California trials. Phorate is considered less effective for this treatment. Other granular insecticides labelled for use on sugarbeet do not have systemic activity and are not effective for aphid control. However, future availability of granular carbofuran is limited due to concerns about avian toxicity. Among foliar insecticide treatments, chlorpyrifos provides good control of the bean aphid but is ineffective against the green peach aphid and leafhopper. Oxydemeton-methyl is highly effective against bean aphid, of modest value against the leafhopper, and (in some areas) has lost effectiveness against green peach aphid. Methomyl has shown moderate effectiveness against the leafhopper and bean aphid but is relatively ineffective against the green peach aphid, unless applied in combination with other insecticides.

Most aphid vectored plant viruses, including those associated with sugarbeet, are poorly controlled by insecticides. However, Rhone-Poulenc data show a 4.5 ton per acre yield increase with aldicarb compared to the untreated check, despite modest virus control. It must also be noted that treatment with aldicarb resulted in substantially higher yields than all alternatives in recent University of California trials. The magnitude of this increase cannot be explained solely by control of foliar feeding insects and virus disease incidence (Vernon Burton, University of California at Davis). However the differences appear to be real and repeatable.

Current Chemical Usage

Assumptions and Data Sources: State acreage, yield and value data are based on 1985-87 production figures provided by the Beet Sugar Research Foundation (Table 32). Yield response from aldicarb and its alternatives is based on locally generated university trials when possible. When this data is not available, data submitted by Rhone Poulenc in their benefits analysis has been used. Prices of aldicarb and its alternatives are based on 19 April 1989 prices listed in AGCHEMPRICE (Table 33). Planting time applications of granular pesticides are not considered to have a significant application cost.

Estimates of aldicarb use are based on reported treated acreage in 1987 and/or 1988. University researchers and sugar company personnel were consulted for these data. Estimates of aldicarb benefits, and benefits of alternatives, are based solely on the treated acreage. Data used in this analysis are summarized in Tables 32-39.

California: Approximately 5.3 percent (13,325 acres) of the harvested acreage was treated with aldicarb in 1987. This is an increase over the amount used in previous years. Preliminary data from 1988 indicate a continuing trend of somewhat higher aldicarb use on the crop. Key pests of the crop are aphids, specifically green peach aphid (*Myzus persicae*) and bean (or cowpea) aphid (*Aphis* spp.). The secondary target pest is the southern garden leafhopper (*Empoasca solana*). This insect does not vector disease but can directly reduce sugarbeet yields from feeding injury.

Two 1988 studies conducted by the University of California (Burton et al., 1988, unpublished data) indicated a yield benefit of 4 to 7 tons per acre yield increase on aldicarb treated sugarbeet. This magnitude of response is even greater than the average reported by Rhone Poulenc (3.6 to 4.5 tons per acre) in a summary of 20 California tests conducted from 1970-84. Using an intermediate figure of 4 tons per acre as the yield benefit on California acreage treated with aldicarb (13,325 acres), increased value of the crop ($34.13/tons) is estimated at $1.8 million. Subtracting treatment costs (aldicarb planting time treatment at 1.6 lb ai/acre ($25.39) indicates a net value of $1.5 million. The 1988 University of California trial indicated an increase of 3.7 tons

per acre compared to carbofuran and 5.5 tons per acre compared to phorate. These differences in yield cannot be explained entirely in control of beet yellows, beet mosaic, potato aphid or leafhoppers, since control levels were not significantly different from the alternative treatments for most of the season.

Foliar applications of methamidophos were applied in two 1988 University of California trials and chlorpyrifos in one trial compared against an aldicarb treatment. Chlorpyrifos, but not methamidophos, provided acceptable control of leafhoppers; however, beet armyworm populations increased on the methamidophos treated plots. Despite relatively low pest pressure in both experiments, aldicarb treated sugarbeet yielded 1.4 to 6.2 tons per acre more than methamidophos or chlorpyrifos treated plots. The basis for this yield increase is unclear.

There is insufficient data to reliably establish the benefit of aldicarb compared to the alternatives; however, substantial yield increases were indicated. For the benefit of the analysis, a conservative figure of 1.5 tons/acre increase is proposed. Cost differential between aldicarb ($25.39, 1.6 lb ai) compared to alternative granular treatments is $11.52 for carbofuran (1.6 lb ai) and $13.09 for phorate (2 lb ai). Cost differential between two foliar applications of Monitor 4WM (1 lb ai + application) is -$6.73/acre; compared to Chlorpyrifos 4E (1 lb ai + application) is $2.63. Aldicarb use on 1988 treated acreage (13,325 acres) is estimated to have increased production by 19,987 tons, compared to alternatives. Average price of California sugarbeet is $34.13, giving a gross return of $682,156. Accounting for cost differential between various alternatives, the net value to producers from use of aldicarb ranged from $507,731 (phorate planting time alternative) to $771,833 (methamidophos foliar application alternative).

<u>Colorado:</u> Approximately 30 to 35 percent of the state acreage is infested with sugarbeet cyst nematode. Typically, 18 percent of the state sugarbeet acreage (6,678 acres) is treated with nematicides. Aldicarb use predominates, although recently some increased use of 1,3-dichloropropene fumigation has occurred, currently involving some 2,000 acres. Aldicarb is typically used at a rate of 5 lb ai/acre, applied at planting. Because of economics, ability to rotate crops is limited. Three year rotations predominate. Sugarbeet are usually the most valuable crop grown in the rotations.

A 2.7 ton per acre benefit from aldicarb was indicated in the Rhone Poulenc estimate for Colorado trials, a figure confirmed by sugar company personnel. Using this figure, the benefit of aldicarb in increased crop production on 4,678 aldicarb-treated acres is estimated at 12,631 tons, valued at $402,916. Subtracting treatment costs ($79.35/acre), net value to area producers was $31,717.

Assuming a 3 ton per acre yield increase from use of 1,3-dichloropropene (12 gal), relative to Aldicarb (5 lb ai) there would be a net increase in crop production on treated acreage of 20,034 tons, valued at $792,745. Compensating for treatment cost differential ($41.51), net return to producers using aldicarb rather that 1,3-dichloropropene is estimated at -$515,541.

<u>Idaho:</u> Approximately 50 percent of acreage is infested with sugarbeet cyst nematode, the primary target pest of the region. Sugarbeet root maggot is generally a minor pest. Estimates of acreage recently treated with aldicarb for one or both pests range from 20 to 40 percent. An average of 30 percent (47,400 acres) will be used as the annual estimate of acreage treated. Typical use involve aldicarb application at 6 lb ai, applied as a split application.

Eight trials conducted by the University of Idaho since 1982 indicated an average yield increase from treatment with aldicarb (6 lb ai, split application) of 4.9 tons/acre. This would result in increased production of 232,260 tons valued at $8.6 million. The net value of this treatment, subtracting treatment costs ($99.72/acre) is estimated at $3.9 million. Granular nematicides have been ineffective in University of Idaho trials. For example, where terbufos (Terbufos 15G) was included for nematode control, yields were equal to or less than the untreated check. Granular nematicides are not considered to be alternatives.

Fumigation with 1,3-dichloropropene at 15 gal/acre gave a yield increase compared to Aldicarb at 5-7 tons/acre in recent University of Idaho trials. Using an average of 5.7 tons/acre the estimated difference in production from using (6 lb ai, split application) instead of 1,3-dichloropropene is estimated at 270,180 tons, valued at $10.0 million. Net return to producers from using aldicarb instead of the fumigation alternative is -$7.8 million, correcting for the $48.23/acre cost differential.

Crop rotation is stressed and contracts require a minimum 2 year rotation. However, longer rotations are not typically possible for many producers due to limited available acreage.

Michigan: Sugarbeet cyst nematode is widespread in the state and has led to large acreages being abandoned. Use of aldicarb on Michigan sugarbeet is estimated at approximately 500 acres. Assuming a yield increase on the treated acreage to be 3.5 tons, increased crop production from aldicarb is estimated at 1,750 tons, valued at $52,850. Net value to producers, subtracting $79.35/acre treatment costs is estimated at $13,190.

Strict rotation requirements are written into Michigan grower contracts. Adherence to these requirements, which has involved abandoning extensive infested acreage, has largely eliminated sugarbeet cyst nematode problems. The Michigan experience has shown the potential benefit of crop rotation as an effective cultural control alternative, where adequate land and suitable alternative crops occur.

Minnesota: The primary target pest of the crop is the sugarbeet root maggot. Sugarbeet acreage is contiguous with North Dakota in the Red River Valley. Estimated useage and control benefits are assumed to parallel that of North Dakota. Estimated acreage treated with aldicarb is 10 percent (29,900 acres). Use is as a planting time treatment at the rate of 1.5 lb ai/acre. Treatments are limited to high risk areas, with alternative treatments (terbufos, chlorpyrifos) used on most of the remaining acreage. Throughout the state, sugarbeet root maggot treatments are applied to approximately 60 to 70 percent of the acreage.

North Dakota data suggest a yield response from aldicarb treatment on heavily infested fields of 4.55 tons/acre. This would indicate an increased production from aldicarb treatment of 136,045 tons, valued at $5.4 million. Net return to producers after treatment costs ($23.81/acre) is $4.7 million. Aldicarb is perceived as having a significant yield benefit in fields that are heavily infested with sugarbeet root maggot, compared to its alternatives. This yield benefit is estimated at 0.9 tons/acre, compared to terbufos and chlorpyrifos, based on North Dakota State University trials. This would indicate a potential loss of production from use of the alternatives of 20,930 to 26,900 tons, valued at $830,293 to $1.1 million. Net value to producers compared to the alternatives is estimated at $522,024 (terbufos) to $498,104 (chlorpyrifos).

Montana: Sugarbeet cyst nematode is the primary target pest of the crop, infesting approxiately 40 percent (67,800 acres) of total acreage. Annually, about 30 percent (13,860 acres) of the acreage is treated for nematodes, essentially all of it with aldicarb. Assuming a 3.5 ton/acre yield increase, increased crop production is estimated at 48,510 tons, valued at $1.9 million. Subtracting control costs ($79.35/acre) the increased net value would be $782,397. Sugarbeet root maggot is an occasional problem. There would be some additional expense associated with treatment for sugarbeet root maggot.

Assuming a 3 ton/acre yield increase on all currently treated acreage, the increased net value of the alternative 1,3-dichloropropene fumigation treatment (12 gal/acre) would be $1.6 million. Correcting for application cost differential ($41.51), the net value of the crop treated with aldicarb (5 lb ai, planting time treatment) compared to the alternative is -$1.4 million. Not all the land is suitable for fumigation and fall soil moisture is erratic.

Nebraska: Most producers use a sugarbeet-corn-bean rotation, occasionally extending rotations with alfalfa. However, approximately 40 percent of the acreage remains infested with nematodes and 20 percent is sufficiently infested that it is treated with nematicides. Aldicarb, typically used at a 5 lb ai rate at planting time, is the predominant treatment. A small amount of the treated acreage (approximately 2,000 acres) is fumigated with 1,3-dichloropropene, particularly in heavily infested areas. Producers typically apply the fumigant in fall, during plowing. In addition a limited acreage that is in transplant sugarbeet is often treated at a 1 lb ai rate to enhance seedling vigor. There is no data to support the benefit of this practice.

A report in Fungicide and Nematicide Tests (Kerr and Hagen, 1976) indicated a 22.6 percent yield response from aldicarb on infested sugarbeet. This is similar to the 24.6 percent yield response reported as the average by Rhone-Poulenc. Using the 22.6 percent figure as the average benefit on the treated acreage, increased yield response from aldicarb treatment is estimated at 4.9 tons/acre (based on average crop production of 21.6 tons/acre). On currently treated acreage, aldicarb is estimated to increase production 56,350 tons, valued at $1.8 million. Treatment costs with aldicarb are estimated at $79.35/acre, giving a net value from treatment of $900,255.

Fumigation is estimated to increase yield by 3 tons compared to aldicarb. Assuming all acreage currently treated with aldicarb was treated with this alternative, increased production would be 34,500 tons valued at $1.l million. Subtracting for cost differential ($41.51/acre) of the 1,3-dichloropropene (12 gal/acre) alternative, the net value of the aldicarb treatment (5 lbs ai) would be -$632,500.

North Dakota: Sugarbeet root maggot treatment is widespread in the region. However, due to cost, alternative insecticides are used on almost all acreage. Use of aldicarb is limited to northern production areas of North Dakota which have a high risk of infestation. This high risk acreage has involved from 5-12 percent of the total state acreage in recent years. Use rates of aldicarb are typically 1.5 lbs ai/acre. Remaining acreage that is treated for sugarbeet root maggot, approximately 65-70 percent of the total, receives treatment with lower cost alternatives.

Recent (since 1982) North Dakota State University trials have indicated yield reductions on untreated acreage at 75.4 percent of the yield on aldicarb treated plots. Based on average yields of 18.1 tons/acre (1985-87 average) this would indicate a yield benefit of 4.55 tons/acre from aldicarb treatment. Assuming that approximately 10 percent of the North Dakota acreage is treated

with aldicarb (16,170 acres) and has a 4.55 ton/acre yield response from treatment, increased production would be 73,574. Gross value is estimated at $2.9 million. Subtracting treatment costs of $23.81/acre gives a net return from aldicarb treatment of $2.5 million. On acreage at high risk of sugarbeet root maggot infestation, yield benefit of aldicarb compared to alternatives is set at the average levels indicated by Rhone Poulenc data. The high risk acreage is set as being the same as the aldicarb acreage, approximately 16,170 acres. Alternatives include 1.5 lb ai terbufos and 1.5 lb ai chlorpyrifos. Carbofuran is no longer recommended for control due to erratic performance. Treatment cost differential is -$10.31 for terbufos and -$11.11 for chlorpyrifos.

Yield benefit statistics are based on the differential control achieved by aldicarb compared to alternatives, discussed in the introductory section (0.9 tons/acre for terbufos and chlorpyrifos). Increased crop production compared to terbufos and chlorpyrifos alternatives are estimated at 14,553 tons ($575,862). Net lost value to producers, adjusting for treatment costs, is estimated at $409,149 compared to terbufos and $396,213 compared to chlorpyrifos.

Oregon: Sugarbeet cyst nematode is the primary target pest in the state. Figures on treated acreage (30 percent, 5,550 acres) yield response from treatment are based on Idaho data. Based on a 4.9 ton/acre yield increase from aldicarb treatment, increased crop production is estimated at 27,195 tons valued at $958,896. Treatment costs are $99.72, based on a split application applying a total of 6 lb ai/acre. Net return to producers is estimated at $405,450. Fumigation with 1,3-dichloropropene (15 gallons/acre) is estimated to give an increased yield of 5.7 tons compared to aldicarb. Increased potential production would increase 31,635 tons with a gross value of $1.1 million. Treatment cost differential ($48.23) gives a net return from aldicarb compared to 1,3-dichloropropene of -$847,774.

Wyoming: Sugarbeet cyst nematode is the primary target pest of the state. The entire production acreage in the Worland area is currently treated with aldicarb. Other areas use lesser amounts of aldicarb. An overall estimate of 60 percent of the acreage (30,660 acres) is treated with aldicarb. This is the highest percentage of acreage treated in any sugarbeet producing state.

Using the Rhone-Poulenc figure of 3.5 ton/acre yield increase from use of aldicarb on cyst nematode treated acreage, the average increased production is estimated at 107,310 tons. Gross value of this production is estimated at $3.9 million. Subtracting treatment costs of $79.35/acre (aldicarb planting time treatment, 5 lb ai) gives a net return of $1.4 million. An estimate of 3 ton/acre yield increase from 1,3-dichloropropene (12 gal/acre) fumigation would result in a yield increase of 91,980 tons on current aldicarb-treated acreage, valued at $3.3 million. Treatment differential between aldicarb ($79.35) and 1,3-dichloropropene applied at 12 gal/acre ($120.86) is $41.51. Potential net crop value from using aldicarb instead of the 1,3-dichloropropene alternative for control of sugarbeet root maggot is estimated at -$2.0 million. However, not all acreage is suitable for fumigation. Furthermore, much of the acreage would need treatment for sugarbeet root maggot, including the entire Worland area (25,000 acres). This area would need additional treatment with planting time treatments of terbufos, carbofuran, or chlorpyrifos at a cost of $12.71 to $13.50 per acre. This would give a net value of approximately -$1.7 million using the fumigation and insecticide treatment. However, it is likely that the extremely high treatment costs would drive out of production the Worland area, including the beet sugar manufacturing plant. If this were to occur, loss in agricultural value would approximate $18.5 million annually, plus value added by processing.

Summary and Conclusions

Production-limiting pest species occur throughout the sugarbeet acreage in the United States. The primary target pests include sugarbeet cyst nematode, sugarbeet root maggot, aphid and leafhopper. Aldicarb is used primarily as a nematicide to control sugarbeet cyst nematode in Wyoming, Colorado, Montana, Nebraska, Idaho, and Oregon. In North Dakota and Minnesota it is used to control sugarbeet root maggot in areas of high pest pressure. Aldicarb is used primarily to control leafhopper and aphid vectored diseases in California. The return from treatment of sugarbeet acreage with aldicarb in 1988 is estimated at $16.0 million. This was due to control of sugarbeet cyst nematode ($7.3 million), sugarbeet root maggot ($7.2 million) and aphids/leafhoppers ($1.5 million). The benefits from aldicarb use are greatest in Minnesota ($4.7 million), Idaho ($3.9 million), North Dakota ($2.5 million), California ($1.5 million), and Wyoming ($1.4 million).

Fumigation with 1,3-dichloropropene is the only alternative for control of sugarbeet cyst nematode. An increase in crop value of $12.9 million is estimated if producers treated with 1,3-dichloropropene instead of aldicarb. However, this estimate assumes that all aldicarb-treated acreage could be fumigated. This figure is therefore conservative since non-economic considerations, such as weather, affect the suitability of fumigation. Despite apparent yield benefits, producers have not readily adopted fumigation with 1,3-dichloropropene for sugarbeet cyst nematode control. High cost and financial risks associated with fall fumigation, difficulties in application, and sensitivity to environmental conditions are reasons that fumigation is not currently used. Fumigation can not reliably provide alternative control for all sugarbeet acreage that is currently treated with aldicarb for cyst nematode control. Granular insecticides/nematicides such as terbufos and carbofuran are not considered to be acceptable treatments for sugarbeet cyst nematode. Inability to effectively control sugarbeet cyst nematode would likely eliminate some sugarbeet production areas, particularly in Wyoming. The loss of aldicarb is expected to eliminate production on approximately 25,000 acres in the Worland area of Wyoming, at an annual loss estimated at $18.5 million.

Alternatives to aldicarb for control of sugarbeet root maggot include chlorpyrifos and terbufos. Under typical infestations, these alternatives provide control comparable to aldicarb. Under high levels of pest infestation, aldicarb provides improved control, estimated at 0.9 tons/acre. In areas of Minnesota and North Dakota where serious infestations of sugarbeet root maggot occur, loss of aldicarb would result in reduced value to producers of $894,317 to $931,203. The other granular insecticides labelled for use (phorate, fonofos, and carbofuran) are less effective and are not widely used.

In California, aldicarb is a superior treatment for control of aphid and leafhopper. Several alternative controls provide equivalent insect control, however, aldicarb provides a comparative yield advantage that can not be explained by differences in pest control alone.

Sugarbeet is grown as a processing crop. Crop value is added by local processing in sugarbeet factories. These factories are often major sources of local employment in rural areas. Loss of aldicarb would have greatest effects on the economic health of communities in the Rocky Mountain region, particularly Wyoming. In these production regions, good control of sugarbeet cyst nematode is critical if the viability of the local beet processing industries is to be maintained.

Table 32. U.S. sugarbeet production and value, 1985-87 (Source: Beet Sugar Research Foundation), and current use of aldicarb

State	Harvested acreage	Crop value	Estimated acreage aldicarb-treated
North Dakota	161,700	$113,338,000	16,170 (10%)
Minnesota	299,000	$219,444,000	29,900 (10%)
Michigan	123,300	$75,900,000	500
Ohio	14,800	$8,419,000	-0-
Idaho	158,000	$147,717,000	47,400 (30%)
Oregon	18,500	$13,137,000	5,550 (30%)
Montana	46,200	$38,007,000	13,860 (30%)
Wyoming	51,100	$38,006,000	30,660 (60%)
Colorado[1]	37,100	$28,837,000	4,678 (18%)[2]
Nebraska	57,500	$39,742,000	9,500 (20%)[2]
Texas	31,200	$21,730,000	-0-
California	203,300	$177,235,000	13,325

[1] For Colorado, only 1986-1987 data used, since sugar production was disrupted in 1985 by bankruptcy reorganization of Great Western Sugar.
[2] Approximately 18-20% of the state acreage is treated with nematicides in Colorado and Nebraska. Some 2000 acres are currently fumigated with 1,3-dichloropropene instead of being treated with aldicarb.

Table 33. Price of aldicarb and its alternatives (Source: AGCHEMPRICE, April 19, 1989)

Insecticide/ nematicide	Price (lb ai)	Comments
Temik 15G	$15.87	$4-$5/acre application if side dressed
1,3-dichloropropene	$9.03 /gal	$12.50/acre application cost
Lorsban 4E	$7.38	$4/acre application cost
Monitor 4WM	$12.06	$4/acre application cost
Lorsban 15G	$8.47	Planting time treatment
Counter 15G	$9.00	Planting time treatment
Furadan 15G	$8.67	Planting time treatment
Thimet 20G	$6.15	Planting time treatment

Table 34. Yield and production benefit associated with aldicarb use on sugarbeet

State	Yield benefit/tons treated acres	Increased production (tons)	Price ($/ton)[1]
North Dakota	4.55	73,574	39.57
Minnesota	4.55	136,045	39.67
Michigan	3.5	1,750	30.20
Idaho	4.9	232,260	37.23
Oregon	4.9	27,195	35.26
Montana	3.5	48,510	38.80
Wyoming	3.5	107,310	36.00
Colorado	2.7	12,631	31.90
Nebraska	4.9	46,550	32.17
California	.0	53,300	. 34.13

[1] Source: Beet Sugar Research Foundation.

Table 35. Estimated production value associated with aldicarb use on sugarbeet

State	Gross production value	Treatment cost $/acre	Production value ($)
North Dakota	2,911,323	23.81[1]	2,526,315
Minnesota	5,396,905	23.81[1]	4,684,986
Michigan	52,850	79.35[2]	13,175
Idaho	8,647,040	99.72[3]	3,920,312
Oregon	958,896	99.72[3]	405,450
Montana	1,882,188	79.35[2]	782,397
Wyoming	3,863,160	79.35[2]	1,430,289
Colorado	402,916	79.35[2]	31,717
Nebraska	1,497,514	79.35[2]	743,689
California	1,819,129	25.39[4]	1,480,807
Total			16,019,150

[1] Planting time treatment of aldicarb at 1.5 lb ai
[2] Planting time treatment of aldicarb at 5.0 lb ai
[3] Planting time treatment of aldicarb at 3.0 lb ai plus sidedress treatment of 3.0 lb ai ($4.50 application cost).
[4] Planting time treatment at 1.6 lb ai

Table 36. Alternative treatments and relative yield response compared to aldicarb treatment of sugarbeet

State	Alternative treatments	Yield differential (tons/acre)
North Dakota	terbufos, chlorpyrifos	-0.9
Minnesota	chlorpyrifos, terbufos,	-0.9
Michigan	no alternative	-0-
Idaho	1,3-dichloropropene	+5.7
Oregon	1,3-dichloropropene	+5.7
Montana	1,3-dichloropropene	+3.0
Wyoming	1,3-dichloropropene	+3.0
Colorado	1,3-dichloropropene	+3.0
Nebraska	1,3-dichloropropene	+3.0
California	chlorpyrifos, methamidophos, phorate, carbofuran	-1.5

Table 37. Production, gross value and treatment cost differentials

State	Alternative Production Differential (tons)	Alternative cost (gross) Differential ($)	Alternative treatment cost Differential ($/acre)
North Dakota	-14,553	-575,862	10.31 to 11.11
Minnesota	-26,910	-1,067,520	10.31 to 11.11
Michigan	-1,750	-13,175	-0-
Idaho	+270,180	10,058,801	-48.23
Oregon	+31,635	1,115,450	-48.23
Montana	+41,580	1,613,304	-41.51
Wyoming	+91,980	3,311.280	-41.51
Worland area			-54.22
Colorado	+14,034	447,685	-41.51
Nebraska	+28,500	916,845	-41.51
California	-19,988	-682,190	-6.73 to 13.09

Table 38. Net return from use of aldicarb alternatives for sugarbeet pests		
State	$ +/- Alternative	Alternative
North Dakota	-396,213 -409,179	Chlorpyrifos, Terbufos
Minnesota	-498,104 -522,024	Chlorpyrifos, Terbufos
Michigan	-21,110	None
Ohio	-0-	
Idaho	7,772,699	Fumigation not always possible due to weather. There will also be some addition costs for sugarbeet root maggot control.
Oregon	847,774	
Montana	1,417,569	
Wyoming	1,720,833 to 1,701,083	Fumigation not adaptable to all acreage. Worland production area (25,000 acres) would likely be driven out of production with loss of aldicarb at an annual loss of $18,500,000+.
Colorado	253,501	Fumigation not always possible due to weather.
Nebraska	522,500	
Texas	-0-	
California	-771,850 to -507,749	

Table 39. Summary of aldicarb economic benefits[1] to U.S. sugarbeet production compared to untreated acreage or to alternatives

State	Benefit compared to untreated ($)	Benefit Compared to alternative ($)
California	1,480,807	507,749 to 771,850[2]
Colorado	31,730	-253,501[3]
Idaho	3,920,312	-7,772,669[4]
Michigan	13,175	-0-
Minnesota	4,684,986	498,104 to 522,024
Montana	782,397	-1,417,569[3]
Nebraska	743,689	-522,500[3]
North Dakota	2,526,315	396,213 to 409,179[5]
Ohio	-0-	-0-
Oregon	405,450	-847,774[4]
Texas	-0-	-0-
Wyoming	1,430,289	1,701,083 to 1,720,833[3] + loss of Worland area production (18,500,000+)

[1] Annual benefit based on current acreage treated with aldicarb. Benefits assessment of alternatives assumes that all aldicarb treated acreage could be treated with the alternatives.
[2] Alternatives for control of leafhoppers and aphids including planting time treatments of Furadan 15G, Thimet 20G, or foliar applications of Monitor 4WM, Lorsban 4E.
[3] Alternative for control of sugarbeet cyst nematode is 1,3-dichloropropene at 12 gal/acre.
[4] Alternative for control of sugarbeet cyst nematode is 1,3-dichloropropene at 15 gal/acre.
[5] Alternative for control of sugarbeet root maggot is Counter 15G or Lorsban 15G.

Aldicarb Use on Sweetpotato

Whitney S. Cranshaw

Sweetpotato is grown primarily as a fresh market crop. Processing uses are secondary but also are significant in some regions, notably North Carolina. USDA figures report sweetpotato acreage of 92,600 acres, producing a total of 11.8 million cwt in 1988. Sweetpotato is produced in 12 states, concentrated in the Southeastern and South-central states. The value of sweetpotato varies due to market demand and processor contract prices. USDA estimates the market value of sweetpotato ranged from $6.43 (Virginia) to $16.67 (Texas) per cwt from 1985 to 1987. However, crop value varies with grade and due to large annual market price fluctuations. Grade values in North Carolina range from $2.75 to $4.00 per bushel for No. 1 grade; $1.25 to $2.50 per bushel for jumbo grade; and $1.25 per bushel for canner grade.

Registration Summary

Aldicarb is registered for control of nematodes at a rate of 10 to 20 pounds (formulation) per acre. User rates are in the middle or upper-middle range of the labelled rate. Aldicarb is not registered for control of insect pests and is not considered to be effective against the most important soil insect pests which attack the crop.

Pest Infestation and Damage

Root-Knot Nematodes, particularly southern root-knot nematode (*Meloidogyne incognita*) and the peanut root-knot nematode (*M. javonica)*, are the most important target pests of sweetpotato controlled with applications of aldicarb. Nematode damage inhibits normal fibrous root development, resulting yield reductions. Root-knot nematode feeding injury also reduces root quality. Black spotting, root deformation, and cracking are associated with root-knot nematode injury to sweetpotato. This can reduce grade and value, resulting in cullage with more serious defects. Serious root-knot nematode problems occur in sweetpotato growing areas of Texas, North Carolina, and Alabama. Less serious damage occurs in Virginia, South Carolina, and Georgia.

Amount of yield loss varies by intensity of nematode infestation. Estimates of yield losses on infested North Carolina acreage that is not treated with aldicarb or its alternatives range from 25 to 40 percent. These estimates are supported by research data from several North Carolina State University trials published in Fungicide and Nematicide Tests. Even when treatments are applied, nematodes reduce North Carolina sweetpotato yields 2 to 6 percent for an annual loss to growers of approximately $2 million (Charles Averre, N.C. State University, personal communication, 1989). Recent trials in Texas (George Philley, Texas A&M University, unpublished data) showed a yield increase of 261 percent when root-knot nematode was controlled.

Pest Management

Current Chemical Usage

Aldicarb is considered by all sweetpotato nematologists and plant pathologists contacted in this study to be the only consistently effective planting time treatment for root-knot nematode. It is effective at suppressing early-season nematode populations, root damage, and plant damage. Alternative planting time treatments with ethoprop and oxamyl are not considered to be acceptably consistent or effective. At present, essentially all planting-time nematicide treatments in North Carolina, South Carolina, Texas, and Alabama use aldicarb. Some ethoprop is used, particularly in Georgia and Virginia, where nematode problems are secondary to problems with various soil insects. Ethoprop is considered to be more effective against soil insects than aldicarb. Little or no oxamyl is used as effectiveness has been considered erratic. Oxamyl is also highly water soluble and leaches too rapidly in most sweetpotato areas to provide adequate persistence.

State sweetpotato acreage, yield data, and crop value data are based on 1986-88 production figures provided by the National Agricultural Statistics Service, USDA. Yield response from treatment with aldicarb and evaluation of aldicarb alternatives is based on locally generated university trials, where possible. When this data is not available, data submitted by Rhone-Poulenc in their benefits analysis will be used. Prices of aldicarb and its alternatives are based on 19 April 1989 price listings in Agchemprice (Ben Mason, El Paso, Texas). These include the following: aldicarb ($15.87/lb ai); 1,3-dichloropropene ($9.03/gal + $12.50/acre application cost). Estimates of aldicarb use are based on estimates of average treated acreage 1986-88. University researchers and Cooperative Extension System personnel were consulted for these estimates. When data were not available, estimates were made based on usage patterns in adjacent state production areas. The benefits of aldicarb and its alternatives were calculated based on current usage. The results of the benefits analysis are presented in Tables 40 - 45. A state-by-state summary of the analysis is presented below.

Alabama: Root-knot nematode is the most important pest of the crop. Nematode control is considered standard practice by most growers, with an estimated 80 percent (5,174 acres) of sweetpotato acreage treated with aldicarb. Sweetpotato production is scattered throughout the state. Problems with nematodes occur in all areas but are particularly acute in the southern growing area of Baldwin County. Yield benefit from use of aldicarb on nematode-infested land is estimated at 30 to 40 percent. Treatment also adds value in additional quality by reducing blemishing and cracking of roots. A figure of 35 percent crop value (yield, quality) response from aldicarb will be used for the benefits analysis on aldicarb-treated Alabama sweetpotato acreage. The crop value on the current aldicarb-treated acreage is estimated at $8.0 million. The loss in value without aldicarb would be approximately $2.8 million.

The loss of aldicarb would force some growers to use 1,3-dichloropropene fumigation. Other growers, would be unable to treat and would sustain substantial yield and quality reductions. The nematode infested acreage that would adopt fumigation in the absence of aldicarb is estimated at 75 percent (4,881 acres). Production costs using the alternative would increase $80,407 and there would not be a yield increase. The remaining untreated acreage (1,293 acres), would sustain a net crop value loss of $645,400. Total loss in crop value and increased production costs in Alabama would be $734,807. Ultimately, many growers unable to adapt to fumigation would likely abandon production of sweetpotato and other crops where adequate nematicide options are unavailable.

California: Aldicarb was reported to have been used on 420 acres in 1985. No treated acreage was reported in 1986-87. Current use of aldicarb is considered insignificant in this benefit analysis.

Florida: Very little sweetpotato production occurs in Florida. Production is limited to small acreages managed by producers not certified to apply Restricted Use pesticides. In addition, aldicarb generally performs poorly in these areas due to a high soil pH. Aldicarb use on sweetpotato is not significant.

Georgia: Root-knot nematode is considered to be a major problem on much of the sweetpotato acreage. However, acreage treated with aldicarb has greatly declined in recent years, and is currently less than 10 percent. Producers have generally switched to ethoprop in control soil insects such as wireworms, which are more serious pests than nematodes in most of the state. The level of nematode control achieved by ethoprop in Georgia apparently is adequate to control the existing pest pressure of root-knot nematode.

Yield response data from use of aldicarb in Georgia are lacking. Since nematode problems are less severe than in North Carolina and Alabama (where treatment data is available), a conservative figure of 15 percent yield benefit from aldicarb treatment has been used for the analysis. The increased crop value from aldicarb treatment is estimated at $110,863. Net value, subtracting aldicarb treatment costs, is estimated at $91,967.

1,3-dichloropropene is considered to be an alternative, of equivalent ability for nematode control. However, there is no current use by sweetpotato growers because of the limitations discussed previously. It is estimated that 90 percent of the acreage currently using aldicarb (390 acres) could adapt to the fumigation alternative. This would require slightly higher treatment costs ($23.04/acre), with no increased yield. Increased production costs would approximate $8,986. The remaining untreated acreage (43 acres) would sustain a net decline in crop value of estimated at $9,197.

Louisiana: Sweetpotato production is located on heavier soils that do not have serious problems with root-knot nematode. Insect problems are of much greater importance than are nematodes. No aldicarb use is reported in the state. Ethoprop is used extensively because of its ability to control soil insects.

Maryland: There is a relatively small acreage of sweetpotato in the state. Production has continued to decline because of inability to compete with other states (notably North Carolina) and increased land values. Root-knot nematodes are a problem in some areas. Approximately 25 to 30 percent of the acreage is treated with aldicarb for control of root-knot nematode. 1,3-dichloropropene fumigation is not used because growers are unfamiliar with the technology. Estimated yield response from aldicarb treatment on currently treated acreage (250 acres) is estimated at 25 percent. Net increased sweetpotato value from aldicarb on currently treated acres is considered to be $75,541.

Sweetpotato production in Maryland is already marginal and declining. Few producers are likely to adapt to the alternative practice of fumigation with 1,3-dichloropropene and granular nematicide alternatives do not exist. If production continues, loss of aldicarb would therefore result in crop value losses equivalent to the untreated alternative ($75,541). Ultimately this acreage would be abandoned for production of sweetpotato and other crops in the absence of alternative nematode controls.

Mississippi: Root-knot nematode does occur but is considered a minor pest on sweetpotato. Sweetpotato areas are capable of rotating crops and, combined with the use of resistant cultivars, cultural practices provide adequate control. No aldicarb is used.

New Jersey: Infestation by root-knot nematode is a major problem. Most state production involves nearly continuous sweetpotato culture, without rotation. Growers routinely fumigate for nematode control, and have used this practice since before aldicarb was registered on the crop. No aldicarb is used.

North Carolina: Root-knot nematodes are the key pest of the crop in most of the state. Approximately 45 percent of the acreage is considered to be seriously infested. In other areas of the state, nematode infestations are less serious, but soil insects are a more serious problem. Approximately 30 percent of the acreage (10,890 acres) is treated with aldicarb; an additional 30 percent treated with 1,3-dichloropropene. Ethoprop and oxamyl are not considered to be effective aldicarb alternatives for nematode control. Chlorpyrifos and ethoprop are used as insecticides where soil insect problems are considered primarily important.

Yield response from aldicarb treatment on nematode infested land is in the range of 25 to 40 percent. An average figure of 33 percent is used for benefit analysis. On the current aldicarb-treated acreage, an estimate of net crop value from aldicarb is $5.5 million.

1,3-dichloropropene is considered to be the best alternative treatment. Fumigation is superior to aldicarb for root-knot nematode control and may result in higher yield increases. For the benefit analysis, the improved control of 1,3-dichloropropene, compared to aldicarb, is estimated at 5 percent. Fumigation has been adapted by many growers, others have resisted use for the reasons discussed previously. Even producers who fumigate use aldicarb as a back-up treatment when weather conditions prevent fumigation.

For the benefit analysis, it is estimated that 90 percent of acreage currently treated with aldicarb would switch to the 1,3-dichloropropene fumigation. Adverse weather and grower inability to switch to fumigation would prevent some acreage from being treated. Crop value losses of 33 percent are estimated from this remaining acreage, a total of $505,078. This would result in a net crop value increase of $431,991 on the treated acreage. Subtracting crop losses that could not be successfully fumigated would result in a net crop value loss to the state of $73,087.

South Carolina: Aldicarb is used on approximately 10 percent of the acreage (450 acres). It is estimated that producers could generally make the switch to fumigation if aldicarb was not available. However, some acreage (estimated at 10 percent, parallel to North Carolina) would not switch to fumigation. Yield and benefit data are assumed to parallel North Carolina. A 33 percent crop loss on current aldicarb treated acreage would result in crop value loss of $208,945. Subtracting treatment costs, net loss is estimated at $189,307.

Yield and benefit data are assumed to parallel North Carolina. The majority of the acreage currently treated with aldicarb that would switch to 1,3-dichloropropene fumigation (90 percent, 405 acres) would have an increase in crop production of 10 percent ($17,037). Net value (subtracting a $23.04/acre treatment cost differential) of the fumigation alternative would be $7,706. Remaining aldicarb-treated acreage that could not be treated with fumigation (45 acres) are assumed to sustain 33 percent crop losses, valued at $18,931. Net loss (subtracting $43.64/acre aldicarb

treatment costs, $1,964) is estimated at $16,967. Overall impact on state production would be $9,261.

Texas: Almost all production occurs in the three county area of Smith, Wood, and Van Zandt counties. These counties are becoming increasingly urbanized which has resulted in high land costs and more limited acreage for rotations. Severe problems with root-knot nematode occur throughout the region. With the loss of fensulfothion, aldicarb became the primary nematicide used on the sweetpotato acreage. However, the industry is in transition with 1,3-dichloropropene fumigation becoming widely accepted in recent years. An estimated two-thirds of state acreage is treated with nematicides. Fumigation is practiced on about 60 percent of the acreage, aldicarb is used on 10 percent (720 acres).

Yield response from aldicarb treatment in Texas A&M University trials on heavily infested land indicated that yields of untreated plots were reduced 38 percent compared to the aldicarb treatment. Total crop value of the 720 treated acres is estimated at $1.4 million. Benefit from aldicarb is approximately $532,740. Net value from aldicarb treatment is estimated at $501,309.

The alternative treatment, fumigation with 1,3-dichloropropene gave a further yield increase of 26 to 28 percent, relative to aldicarb, on heavily infested land. Use of the fumigation alternative on current aldicarb-treated acreage would result in a crop value increase of $135,353. Net value increase ($23.04/acre increased treatment costs) is estimated at $123,927.

Inability to control nematodes, combined with economic pressures related to land values, will likely act to eliminate future sweetpotato acreage. This follows a trend to decreased acreage in recent years. However, adaptation to fumigation appears to be an acceptable alternative, if growers were forced to abandon granular nematicides.

Virginia: Less than 5 percent (48 acres) is currently treated with aldicarb. Formerly, a large percentage of the crop was treated. However, overall production has declined and much of the nematode infested acreage has been taken out of production due to poor sweetpotato prices. Ethoprop is widely used as both a nematicide and insecticide. Nematode problems on remaining sweetpotato acreage are minor and insect pests are off greater concern. Chlorpyrifos is widely used as the primary insecticide.

Fumigation is not considered to be an alternative. Value of the crop is marginal and growers who would continue to grow the crop would sustain an estimated crop loss of 33 percent, paralleling North Carolina. The value of the crop grown on the current acreage that is treated with aldicarb is estimated at $36,705. Net value (minus aldicarb treatment costs) is $10,018. This current benefit figure would also be the loss associated with the alternative, fumigation with 1,3-dichloropropene. Furthermore, it is likely that the acreage currently treated with aldicarb would ultimately be retired from sweetpotato production in the absence of adequate nematode control alternatives.

Chemical Alternatives for Pest Management

The only widely accepted alternative nematicide is the fumigant 1,3-dichloropropene. Use rates in sweetpotato are typically 6 gal/acre (6 fl oz/100 row-ft). 1,3-dichloropropene is generally considered to be a more effective nematicide than is aldicarb. For example, crop value in 1987-88 Texas A&M University trials (George Philley, unpublished data) gave a return of $303 to $527 per

acre (26 to 28 percent) greater than aldicarb treated sweetpotato. In N.C. State University trials, yield increases were 5 to 15 percent higher when 1,3-dichloropropene fumigation was used compared to aldicarb (Charles Averre, personal communication, 1989). At present 1,3-dichloropropene use in North Carolina is approximately the same as aldicarb; producers in New Jersey have long used fumigation as the primary means of control. Use of 1,3-dichloropropene in Texas has greatly increased in recent years, at the expense of aldicarb. Very little 1,3-dichloropropene is presently used in the other sweetpotato areas with root-knot nematode infestations.

There are several reasons for grower resistance to 1,3-dichloropropene as an alternative to aldicarb. Fumigation is done as a separate operation, that is not compatible with applications of fertilizer or herbicide. The fumigation is best applied in spring before planting, but requires at least 2 weeks after application before planting can begin. If soils remain cool or wet after application, longer planting delays are required to allow the fumigant to dissipate before planting. These planting delays can result in reduced potential yield. In addition, many producers are not trained in the proper use of fumigation equipment. The fumigant is considered highly hazardous and requires additional equipment to apply. On hilly topography, it is not always possible to apply the fumigant consistently through the field. Even among growers who currently use 1,3-dichloropropene, there is interest in retaining aldicarb as a back-up treatment in case weather and field conditions prohibit the use of fumigation.

Ethoprop and oxamyl are not considered to be alternatives to aldicarb. Ethoprop has always failed to provide adequate control and is considered to be a poor nematicide. Oxamyl is too readily soluble in water and is rapidly lost from light soils. Crop value compared to these alternatives is considered equivalent to the untreated alternative.

Non-Chemical Management Alternatives

Crop Rotation: Crop rotation to non-susceptible crops is widely recommended as an effective means of limiting root-knot nematode problems. Producers recognize the value of rotation, but are careful in implementation of this alternative since alternative crops in most sweetpotato areas are also hosts of the root-knot nematode. Ability to rotate crops has been further restricted in some areas (e.g., Texas) since production occurs in areas of rapidly increasing land values due to suburban development.

Resistant Cultivars: There has been development and distribution of sweetpotato cultivars that have some resistance to root-knot nematode. These cultivars are used effectively in production areas where root-knot nematode infestations are not severe (e.g., Louisiana and Mississippi). Under conditions of severe root-knot nematode incidence (e.g., Texas, North Carolina, and Alabama), resistance is not currently considered sufficient to provide control.

Summary and Conclusions

Aldicarb is used as a nematicide on sweetpotato. Southern root-knot nematode, *Meloidogyne incognita*, is the primary target pest for aldicarb applications. Peanut root-knot nematode, *M. javonica*, is a target pest in some production regions. Approximately 18.5 percent (17,965 acres) of U.S. sweetpotato acreage is currently treated with aldicarb. Greatest use is in Alabama, where 80 percent of acreage is treated with aldicarb. Approximately 25 to 30 percent of acreage is

treated in North Carolina and Maryland. South Carolina, Texas, Georgia, and Virginia also reported some aldicarb use. Net producer return from use of aldicarb, compared to the no treatment, is estimated at $8.5 million annually. The greatest benefits are in North Carolina ($5.5 million), Alabama ($2.6 million), Texas ($501,309), and South Carolina ($189,307).

Aldicarb is considered to be the only effective planting time treatment currently registered for use on sweetpotato. Fumigation with 1,3 dichloropropene is the most effective alternative treatment. Fumigation is currently widely used on sweetpotato acreage in New Jersey, Texas, and North Carolina. Fumigation is not adaptable to all sweet potato acreage. Reasons for not adapting to fumigation include: inability to apply on hilly topography, requirement for a delay between treatment and planting, higher cost (approximately $23.04/acre), unfamiliarity of producers to safely and effectively apply fumigants, and the need for an additional field operation. Fumigation is considered to be equal or superior to aldicarb for control of root-knot nematodes on sweetpotato. A switch to 1,3-dichloropropene fumigation would result in a net crop value increase of $474,219.

Approximately 3,158 acres currently treated with aldicarb would not be treated with 1,3-dichloropropene. This acreage would sustain yield and quality loss from nematodes that ultimately may force it to be abandoned. This acreage is concentrated in Alabama (1,293 acres), North Carolina, (1,089 acres), and Maryland (250 acres). Value of the crop loss on acreage not able to be treated with the aldicarb alternatives estimated at $1.3 million. Net value associated with aldicarb treatment, compared to the 1,3-dichloropropene alternative, is estimated at $800,356. Loss of aldicarb would have greatest impact in Alabama ($734,807) and North Carolina ($73,087). Texas would see a net increase in value ($123,927) from switching remaining acreage to the 1,3-dichloropropene alternative.

Table 40. Sweetpotato production and value, 1985-87			
State	Acreage (1985-87)[1]	Average Production 1985-87 (cwt)[1]	Aldicarb-treated acerage (1988)[2]
Alabama	6,467	755,000	5,174 (80%)
California	6,933	1,396,333	-0-
Georgia	5,767	847,333	433 (7.5%)
Louisiana	20,000	2,465,000	-0-
Maryland	933	137,000	250 (25-30%)
Mississippi	5,066	573,333	-0-
New Jersey	2,233	262,667	-0-
North Carolina	36,333	5,216,667	10,890 (30%)
South Carolina	4,500	483,333	450 (10%)
Tennessee	933	117,333	-0-
Texas	7,200	841,000	720 (10%)
Virginia	967	115,000	48 (<5%)
Total	97,333	13,210,000	17,965

[1] Average harvested acreage and production, 1985-1987. Source: National Agricultural Statistics Service.
[2] Estimated acreage (percent) treated with aldicarb in 1988.

Table 41. Estimated crop value associated with aldicarb treatment of sweetpotato			
State	Average crop price (cwt)[1]	Average crop value, total	Average crop value, aldicarb treated acres[2]
Alabama	13.28	10,026,400	8,021,120
Georgia	11.63	9,854,483	739,086
Maryland	9.42	1,290,540	345,804
North Carolina	10.70	55,818,336	16,745,500
South Carolina	13.30	6,331,662	633,166
Texas	16.67	14,019,470	1,401,947
Virginia	6.43	739,450	36,705

[1] Average price, 1985-87. Source: National Agricultural Statistics Service.
[2] Total value of acreage treated with aldicarb (Table 40).

Table 42. Estimated crop value associated with aldicarb treatment of sweetpotato

State	Estimated yield increased (%)[1]	Estimated value ofincreased yield[2]	Net value[3]
Alabama	35	2,807,392	2,581,599
Georgia	15	110,863	91,967
Maryland	25	86,451	75,541
North Carolina	33	5,526,015	5,050,775
South Carolina	33	208,945	189,307
Texas	38	532,740	501,309
Virginia	33	12,113	10,018
Total		9,284,519	8,500,516

[1] Estimated average yield response from aldicarb, compared to untreated, on current aldicarb-treated acreage.
[2] Total crop value of aldicarb-treated acreage (Table 41) X percent yield response from treatment.
[3] Estimated value of increased yield from aldicarb treatment - treatment costs. Treatment costs estimated at $43.64 (2.75 lb aldicarb, ai @ $15.87 lb).

Table 43. Estimated potential use of 1,3-dichloropropene alternative on sweetpotato acreage currently treated with aldicarb

State	Potential use of alternative chemical		
	Possible	Not possible[1]	Loss of production ($) value[2]
Alabama	4881 (75%)	1293 (25%)	645,400
Georgia	390 (90%)	43 (10%)	9,197
Maryland	0 (0%)	250 (100%)	75,541
North Carolina	9801 (90%)	1089 (10%)	505,078
South Carolina	405 (90%)	45 (10%)	18,931
Texas	720 (100%)	-0-	-0-
Virginia	0 (0%)	48 (100%)	10,180

[1] Acreage would likely be taken out of sweetpotato production in the absence of aldicarb or suitable planting time alternative.
[2] Net value of acreage currently treated with aldicarb (Table 42) X percent acreage (column 2) that would not likely be treated in absence of aldicarb.

Table 44. Estimated change in value from use of 1,3-dichloropropene alternative on sweetpotato acreage currently treated with aldicarb. Estimates limited to acreage which may potentially shift to the alternative in absence of aldicarb

State	Yield (%) increase with aldicarb alternative	$ Value (gross) change from alternative[1]	$ Value (net) change from alternative[2]
Alabama	0	-0-	-89,407
Georgia	0	-0-	-8,986
North Carolina	10	454,570	431,991
South Carolina	10	17,037	7,706
Texas	27	135,353	123,927
Total		606,960	465,231

[1] Net value of aldicarb treated acres (Table 42) X % acres capable of being treated with the alternative (Table 43) X % value increase from use of the alternative.
[2] Treatment cost of 1,3-dichloropropene is estimated at $66.68 (6 gal Telone II @ $9.03 + $12.50 application cost). Cost differential compared to aldicarb (2.75 lb ai @ $15.87 = $43.64) is $23.04. Net value is calculated at gross value - treatment cost differential on current aldicarb-treated acreage that could be treated with the alternative.

Table 45. Economic effect on sweetpotato production associated with loss of aldicarb and substitution with 1,3-dichloropropene alternative

State	$ Value <loss> on untreatable acreage	$ Value <loss> of alternative	Net value <loss>
Alabama	-645,400	-89,407	-734,807
California	-0-	-0-	-0-
Georgia	-9,197	-8,986	-18,183
Louisiana	-0-	-0-	-0-
Maryland	-75,551	-0-	-75,541
Mississippi	-0-	-0-	-0-
New Jersey	-0-	-0-	-0-
North Carolina	-505,078	431,991	-73,087
South Carolina	-16,967	7,706	-9,261
Tennessee	-0-	-0-	-0-
Texas	-0-	123,927	123,927
Virginia	-10,180	-0-	-10,180
Total	-1,262,373	462,017	-800,356

Field Crops

Aldicarb Use on Cotton

Robert G. Jones, Thomas F. Leigh, Mitchell P. Roof and William P. Scott

Aldicarb received its first U.S. registration for use on cotton in 1970. In 1988 the total planted acres of cotton in the United States was estimated to be 12.2 million acres. Of this total 3.9 million acres (25 percent) were treated with aldicarb. Aldicarb is registered and used to control several important cotton pest in all major cotton growing areas. Current aldicarb usage against principal target pests is summarized in Table 46. Estimated yield losses to pests that could be controlled with aldicarb are presented in Table 47. Cotton is an important crop in the United States in terms of both domestic consumption and foreign trade. The U.S. farm production for 1987 was estimated to be 14.8 million bales, with a value of $4.5 billion. In niversity trials conducted throughout most of the United States from 1980 through 1985, cotton in the Southeast, Mid-South, and Southwest treated with aldicarb increased net profit over that resulting from seed treatments, foliar treatments, or other granular systemic treatments by $18.08, $29.33 and $27.50 per acre, respectively.

Pest Infestation and Damage

Thrips: Thrips infest cotton in all major cotton-producing states and usually predominate on seedling plants. The following species of thrips attack cotton: *Frankliniella exigua* Hood; tobacco thrips, *F. fusca* (Hinds); *F. gossypiana* Hood; western flower thrips, *F. occidentalis* (Pergande); flower thrips, *F. tritici* (Fitch); onion thrips, *Thrips tabaci* Lindeman; and soybean thrips, *Sericothrips variabilis* (Beach). The most common of these are the flower thrips and their closely related species, tobacco thrips and onion thrips. Two or more species may be found in the same cotton field, often on the same plant, although one species usually predominates in a population. Some species, such as onion thrips and eastern flower thrips, occur across the entire Cotton Belt. Tobacco thrips are confined to approximately the eastern half of the United States. The western flower thrips, *F. occidentalis,* until recently confined to the western half of the Cotton Belt, has now spread into the Mid-South where it is a major pest of bloom stage cotton plants. Other thrips species may also become more numerous on plants beyond the seedling stage of growth.

The 1987 NAPIAP aldicarb questionnaire indicates that a yield loss of 10 percent may be expected in the absence of control when infestations of thrips exceed economic thresholds. Thrips cause enough damage to result in recommendations for their control in most states. Only Arizona and California do not consider thrips to be pests of serious enough importance to warrant general recommendations for their control. In California, the western flower thrips is considered to be a major predator on eggs of spider mites. Control of thrips in that state is often practiced only in seasons with unusually cool spring weather and associated severe thrips damage.

Fifteen of 16 major cotton-producing states recommended aldicarb for thrips control. When high thrips numbers persist after 4 to 6 weeks in aldicarb treated cotton, an additional application of a foliar insecticide may be required. Foliar sprays are applied either by ground or by air. Application costs are estimated to be $.75 to $1.00 by ground and $1.75 to $2.00 per acre by air. A number of alternative insecticides to be used as foliar sprays are cited in Table 48. Many of these alternative insecticides destroy the biological control balance of cotton fields, resulting in outbreaks of other pests.

<u>Cotton Aphid:</u> The cotton aphid, *Aphis gossypii* Glover, occurs wherever cotton is grown. Severe infestations stunt young plants and yield losses may be expected in the absence of control when cotton aphid infestations exceed economic thresholds. When heavy infestations occur during the main fruiting period (from early-bloom to full-bloom), the older leaves turn yellow and are shed, causing premature opening of bolls and development of immature fiber. Research by Scott (1987) and Andrews (1989) during the last several years documents that light infestations of aphids early and moderate-to-heavy populations during the peak fruiting period can reduce yield significantly. Also, honeydew secretions from the aphids drop on the fiber, making it sticky. A fungus often develops in the honeydew deposits, which causes the plants to appear black or sooty. Fiber picked from such plants is stained, sticky, and of low quality; seeds are low in viability and light in weight. Sticky fiber is a major concern of the cotton mill in spinning cotton fibers (Frank Carter, Cotton Incorporated, personal communication).

Aphids may be controlled with aldicarb or foliar applications of insecticides (Table 48). Aldicarb applied for thrips will provide effective control of aphids during the seedling stage of plant development. Later infestations may occur and will commonly require either a foliar application of one of the insecticides cited in Table 46 or a sidedress application of aldicarb. As indicated earlier, aphids may be difficult to control with foliar sprays and pesticide resistance in this pest is suspected.

<u>Cotton Fleahopper:</u> The cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), is generally distributed across the Cotton Belt but causes the most serious damage in the blacklands of Texas, where it is often more injurious than the boll weevil. About 10 million acres of cotton are exposed to attack in Texas, Oklahoma, New Mexico, Louisiana, Mississippi, and Arkansas. The cotton fleahopper feeds on and destroys small squares, particularly during the early-fruiting stage of plant development. The 1987 NAPIAP aldicarb indicates that, when no treatment is applied, yield can be reduced by 20 percent when infestation is severe.

<u>Lygus Bugs:</u> Lygus bugs are the principal insect pests of cotton in Western Areas of the United States. They are especially destructive where extensive alfalfa hay and seed crops are produced near cotton fields, and where large pasture areas dry up in early summer. In the South, lygus bugs often become abundant on weeds and leguminous crops, and may move to nearby cotton and cause severe damage. Lygus bug infestations result from migrations from nearby native, crop and weed hosts as these plants mature, or are harvested.

Lygus hesperus Knight is the predominant species in western areas and the tarnished plant bug (*L. lineolaris* [Palisot de Beauvois]) is prevalent in the South. Other species of lygus bugs damage cotton, but they are usually of minor importance. About 6 million acres of cotton are exposed to attacks of lygus bugs. Losses in the absence of control, when infestations exceed economic thresholds, average about 15 percent, but the 1987 NAPIAP aldicarb questionnaire indicates that individual field loss can exceed 70 percent. Scott (1986) found yield loss in large plots from high populations of Lygus. Lygus bugs are key insect pests of cotton because they usually attack plants in the early fruiting stage. If insecticides are applied for control, beneficial insects important to control of spider mites and bollworms are killed, leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex, beet armyworms, and cabbage loopers. Lygus damage reduces yield and fiber quality. It causes the lint to be spotted and lower in grade. Injured plants develop abnormally, become tall and whiplike and have fewer fruiting branches.

In California and Arizona, safflower is treated for control of lygus bugs to reduce the numbers that migrate to cotton as the safflower matures. Also, alfalfa may be cut for hay in strips to hold populations in the uncut portions of the field and to prevent migration to cotton when the entire field is harvested for hay. This procedure requires considerable management of the alfalfa crop and is not popular with most producers, especially those who do not grow cotton.

Aldicarb is used in anticipation of lygus or plant bug infestations during the early-to mid-season fruiting stage of cotton plant development. These sidedress applications may be made at layby, or before the plants have become sufficiently tall to be damaged by the tractor. Foliar sprays of acephate, naled, dimethoate, dicrotophos, chlorpyriphos, methamidophos, pyrethroids, malathion, azinphosmethyl, methomyl, trichlorfon, methyl parathion are also used for control (see Table 48). An estimated 220,500 acres of cotton are treated to control lygus bugs with aldicarb at the dosage rate of 0.3 to 1 pound active ingredient (lb ai) per acre.

Leafhoppers: The southern garden leafhopper, *Empoasca solana* DeLong, occurs on cotton from southern California across the Cotton Belt, but is a pest of this crop only in the Imperial Valley of California. Adults and nymphs suck sap from veins on the underside of mature leaves, mostly on the lower half of the plant. Severe infestation may cause plants to shed squares and small bolls. Larger bolls may become soft and spongy, and fail to mature. Yield loss may approach 100 percent.

In the Imperial Valley infestations of southern garden leafhopper develop on sugarbeet and move to nearby cotton as beets are harvested. While there are a number of other hosts of this insect, they do not appear to contribute significantly to infestations of cotton.

Cotton Leafperforator: The cotton leafperforator (*Bucculatrix thurberiella*) is a cotton pest in the low desert areas of Arizona and California. This insect feeds on the leaves, initially tunneling within the leaf, and later consuming all except the upper epidermal and veinal tissue. When severe infestations occur, the leafperforator will cause complete defoliation of cotton.

Whitefly: The sweet potato whitefly (*Bemesia tabaci*) is a pest of cotton only in the low desert areas of Arizona and California. Whitefly are sapsucking insects, related to aphids, that feed on the lower leaf surfaces of cotton plants and deposit honeydew on leaves and the cotton lint in open bolls. Infestations are most severe on field margins. Whitefly outbreaks are commonly associated with destruction of their natural enemies by insecticides.

Whitefly, like aphids, produce honeydew which, if deposited on fibers, will reduce cotton quality and may interfere with picking, ginning, and spinning. The sweetpotato whitefly vectors the leaf crumple virus of cotton as well as viruses of several vegetable crops in southern California desert valleys. The greatest economic threat to agriculture in that region is spread of the viruses to fall and winter vegetables which may be completely destroyed.

Spider Mites: A number of species of this pest group attack cotton, and often cause serious damage. The most important pests are: Carmine spider mite, *Tetranychus cinnabarinus* (Boisduval); desert spider mite, *T. desertorum* Banks, *T. lobosus* Boudreaux; Pacific spider mite, *T. pacificus* McGregor; Schoene spider mite, *T. schoenei* McGregor; strawberry spider mite, *T. turkestani* Ugarov & Nikolski; tumid spider mite, *T. tumidus* Banks; two-spotted spider mite, *T. urticae* Koch; and *T. ludeni* Zacker.

Outbreaks of spider mites are most likely to occur following application of a pesticide that destroys the predaceous insects and mites; however, some insecticides used in a treatment schedule for boll weevil, bollworm, or tobacco budworm may also suppress spider mite populations. The entire U.S. cotton production area is exposed to attacks of spider mites. Losses in the absence of controls when infestations exceed economic thresholds average about 4 percent of crop yield.

Aldicarb, applied at planting time or as a fruiting stage sidedress, provides control or suppression of spider mites for 3 to 5 weeks after application. Fields may be reinvaded after this initial control period, or the remaining spider mites may move to untreated foliage. In the absence of a natural predator complex, spider mite infestation resurgence may necessitate additional insecticide treatments.

Nematodes: Nematodes are pests of cotton in most states and are of greatest importance in lighter soil types. Aldicarb use is seldom directed at nematode control, with most use at planting time at rates considered too low for nematode control. Yield losses caused by nematode infestation are estimated at 3.5 percent in Georgia (J.L. Crawford, R.E. Motsinger and W.C. Powell, University of Georgia, personal communication). Nematicide treatments can be justified on 260,000 acres (30 percent) in Georgia, but approximately 20 percent is currently treated. In Mississippi, lint yield was 50 to 79 percent higher, respectively, with than without aldicarb treatment due to control of nematodes and insects (J.C. Bailey and E.B. Minton, USDA-ARS). Plant-parasitic nematodes cause an estimated 7 percent loss annually to Louisiana cotton growers (Charles Overstreet, Louisiana State University, personal communication). It is estimated that 350,000 acres were treated with a nematicide in 1986.

Yield Responses

In the far West, yield responses to use of aldicarb have been variable, with yield increases most commonly associated with planting-time applications of the product. Positive yield response to aldicarb sidedress applications in early-square formation and early-bloom stage cotton has usually been associated with severe infestations of thrips, spider mites, or lygus bugs. The NAPIAP questionnaire revealed the general opinion among growers in Eastern cotton production states that aldicarb will enhance cotton yield beyond production expected through insect control. In California, there is evidence that treatment of cotton with aldicarb may increase the drought resistance (Eric Natwick, personal communication).

Early in the growing season roots, stems, leaves, and fruit of the developing cotton plant are vulnerable to insect pest injury. Nematodes have been shown to delay maturity and reduce yields by damaging the root system. Delays in cotton maturity are usually greatest when damage to terminal buds and leaves occurs during early plant development. Recovery from damage takes time. This critical area of insect damage to young plants is during the early-squaring stage. By the time a cotton plant reaches the sixth to seventh true leaf stage of development, the terminal bud already contains several mainstem nodes and 4 to 5 developing primordial squares.

Durant (1985, 1986 and 1987) reported on the yield response of various cotton cultivars to early-season applications of chlordimeform and aldicarb. High numbers of thrips significantly reduced yield and earliness in the no-aldicarb plots for some cultivars.

Scott et al. (1985 and 1986) found that higher numbers of aphids in untreated cotton caused yield reduction. Aldicarb had a significant effect on square production and significantly reduced the number of squares formed than the same treatment without aldicarb. Aldicarb also significantly reduced boll retention. In every case where significant interactions occurred, the treatment with aldicarb had higher numbers of bolls and an increase in yield over that obtained with the same treatment without aldicarb. Scott (unpublished) found that cotton treated with aldicarb matured earlier and had higher yield than cotton treated with foliar sprays.

Under favorable crop production conditions, there have been reports of yield increase with planting-time of aldicarb, but there is little or no evidence of cotton yield increases attributable to aldicarb unless an insect or spider mite infestation has been controlled. Yield increases of ¼ to ¾ bale per acre have been reported with severe infestations of the strawberry mite or western flower thrips. In the Imperial Valley uncontrolled infestations of the cotton leafperforator may result in total crop destruction (Leigh, 1989).

Non-Chemical Management Alternatives

Non-chemical control methods for the arthropod pests against which aldicarb is used are very effective in some situations but are not universally applicable. Cultural practices that will aid in suppression of infestation development within a field may be insufficient in managing invading populations of Lygus spp., spider mites, or aphids. The beneficial arthropods which are highly effective against aphids, armyworms, bollworms, and spider mites in the San Joaquin Valley of California will be eliminated by pesticides directed against the boll weevil, bollworms, or pink bollworm.

Cotton cultivars possessing the nectariless character that gives some tolerance to lygus bugs are now available to some extent. These cultivars may have much impact on reducing the need for insecticidal control of nectar feeding pests, but this nectariless factor often results in leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex since parasites and predators may also be deprived of nectar. The impact will be increased if the smooth character can be incorporated into the nectariless cultivars, thus providing tolerance to the bollworm-tobacco budworm complex.

Thrips are preyed upon by pirate (*Orius* spp., bigeyed *Geocoris* spp., and damsel *Nabis* spp.) bugs. These predators usually are not present in sufficient numbers in early spring to provide effective control. Other nonchemical methods either are not available or are impractical for control of thrips on cotton. Late planted cotton may escape thrips injury in the Southeast, but yields will be reduced by lateness.

The cotton aphid is usually attacked by parasitic wasps (*Lysiphlebus*, etc.) and preyed upon by several predators (Coccinellidae, *Chrysopa*, etc.). Heavy aphid infestations can occur on seedling cotton in early spring which may be controlled by these natural enemies. When warm weather arrives, if the natural enemies are not sufficient to bring the aphids under control severe damage may occur. Nonchemical methods, other than the naturally occurring parasites and predators previously mentioned, are unavailable for control of cotton aphids.

The cotton leafperforator is usually effectively controlled by parasites. These natural enemies are destroyed by the insecticides used for control of pink bollworm and other pests, resulting in severe perforator outbreaks.

There are no effective nonchemical controls for this pest except its parasites. In the absence of insecticide use a parasite, (*Eritmoceras haldemani*) provides excellent control. Insecticides used to control pink bollworm, bollworm, and boll weevil destroy this and related parasite species.

Predaceous mites, other predators, and fungal diseases often hold spider mite infestations at low levels. Other nonchemical control methods are not available.

Entomophagus Arthropods: The importance of natural populations of entomophagus arthropods (beneficial parasites, and predators) in suppressing cotton insect pests has been reviewed by Newsom and Brazzel (1968), Ables et al. (1983), and Van den Bosch and Hagen (1966). The conservation of parasites and predators has been stressed in integrated pest management research (IPM) (Ables et al., 1983 and 1984). The economic benefits derived from these arthropods has been demonstrated by the Boll Weevil Eradication Program. With the eradication of the boll weevil the need for early-season chemical treatment schedules was eliminated. With beneficial arthropod populations present the cost of *Heliothis* control was greatly reduced (Carlson and Suguiyama, 1985).

Adverse effects of aldicarb on these entomophagus arthropods is not measurable when used at label rates (0.34 to 0.84 g ai/ha) and applied in the seed furrow at planting. Large plot studies by Scott (1989) in Mississippi, whole field studies by Rummel and Reeves (1971) in Texas, area-wide biological control demonstrations in North Carolina by Jones (1989), and whole and split field IPM studies in South Carolina by Roof and Jones (1989) have also demonstrated little impact. Aldicarb used at these rates and application timing were not detrimental to the entomophagus arthropods which could then be relied on for control or management of lepidopterous pest populations.

Aldicarb used at higher rates (1.12 to 3.4 kg ai/ha), when applied in the seed furrow at planting (the higher label rates for nematode control) and as a side-dress application to developing cotton plants, has a detrimental effect to the entomophagus arthropods. This is mentioned by Ables et al. (1983) and has been studied by Ridgway et al. (1967), Bariola et al. (1971) and Timmons et al. (1973). The effect varies dependent on the specific arthropod, as studied by Ridgway et al. (1967) and Scott et al. (1985). Aldicarb is highly toxic to thrips, bigeyed bugs, pirate bugs and damsel bugs, important predators in the biological balance of cotton field ecosystems. This group of predators utilizes plant tissues as a source of moisture, particularly in the absence of sufficient prey. While aldicarb is highly effective against several insect and mite pests of cotton, destruction of the natural enemy complex by this product may leave cotton fields vulnerable to colonization by spider mites, lygus bugs and several lepidopterous pests. Fields must be monitored carefully for such pests and their natural enemies and remedial action taken when necessary (Rude, 1984).

When aldicarb is used at higher rates, it is no less destructive of the beneficial fauna than the broad- spectrum pesticides used as alternatives for aldicarb. Lingren et al. (1968) found that both dicrotophos and monocrotophos adversely affected these arthropods. Scott et al. (1985) found no adverse effect from various aldicarb rates (1.13, 0.56, 0.28 kg ai/ha) at planting or a single application of dimethoate (0.22 kg ai/ha). Laster and Brazzel (1968) showed that predator populations could tolerate early season, low dosage, foliar applications. However, second applications of the chemicals that affected them the least reduced them to the same levels as the harsher materials. Disulfoton, the other granular formulation of systemic insecticides that is an alternative to aldicarb, has similar effects as aldicarb at the higher rates (Ridgway et al., 1967).

Chemical Alternatives for Pest Management

Alternative chemical controls for the cotton pests currently controlled with aldicarb are cited in Table 48. Several of these insecticides are highly toxic, necessitating use of specialized safety equipment for their handling, mixing and application. They may also require repeated applications. While most may be applied by ground sprayers or aircraft, the selective miticide dicofol must be applied by ground as a directed spray.

Potential for Pest Resistance

Aldicarb reduces the likelihood of secondary pest buildups of aphids and mites. By eliminating or greatly reducing the need for foliar sprays, aldicarb could reduce the selection pressure for pesticide resistance to foliar applied insecticides.

Integrated Pest Management

Another important factor that contributes to aldicarb use in cotton is a general awareness by farmers and private consultants of the importance of controlling early-season cotton pests with respect to timely fruiting development and being able to manage crop growth and development throughout the season. The importance of aldicarb is emphasized because the earlier maturing varieties currently grown need to set fruit early in order to produce a good yield. Cotton farmers are moving toward an earlier maturing crop that involves a shorter production. Aldicarb enhances earliness and is especially suited to integrated pest management. In recent years, no management technique has shown greater potential to increase growers profits than the production of an early maturing crop. Earliness in cotton is influenced by a complex of factors that affect the crop from planting to harvest. These factors can include early-season insects and the presence of nematodes.

Comparative Performance Evaluation

Extensive research over the last 15 years has shown that aldicarb controls a broader spectrum of cotton pests for a longer period of time than most other registered products. The systemic activity of aldicarb in the terminal bud protects early squares and other plant tissue from damage. Because planting-time applications of aldicarb provide continuous protection from insect pests and nematodes for up to 5 weeks from the time of plant emergence, aldicarb cotton grows off faster than untreated cotton or cotton treated with alternative compounds. Residual activity may persist for 5 to 6 weeks, depending on use rate, pest levels, and soil types. Seedling vigor is an important physiological factor contributing to earliness.

Economic Analysis

There have been previous attempts to measure the economic benefits that arise from the use of aldicarb in cotton production. These benefits can be associated with yield losses from pest damage, reduced quality, higher costs from alternative controls, increased weed control costs without aldicarb and a general loss of earliness important to regions with significant risks from shorter growing seasons. Cooke (1988) estimated that in the four Delta states (Arkansas, Louisiana, Mississippi and Missouri) the annual economic benefit from aldicarb use was $74.3 million in 1987. Paxton et al. (1989) estimated that in Louisiana the risk management benefits of

aldicarb could be as high as $97.46 per acre, depending upon the level of farmer risk aversion. With 325,000 acres of aldicarb treated cotton in Louisiana, annual benefits could be as high as $32 million in Louisiana alone.

This study measured the economic benefits of aldicarb by surveying production experts in the cotton producing states. Experts were asked to estimate changes in pest control practices, yields, quality and other production practices that would likely occur if aldicarb was not available. These estimates were converted, using standard pesticide prices and average state yield and price data, into the benefit estimates appearing in Table 51. The total annual benefit from aldicarb use on cotton is estimated to be slightly more than $89 million. The majority of the benefits arise in the Southern states of Mississippi, Louisiana, Alabama, Arkansas, Missouri and Texas. Projected yield losses account for 80 percent and quality losses account for 8 percent of the total benefits from aldicarb use. As indicated, by the pest control cost estimates, the chemical alternatives are in many cases less expensive, but they may also be less effective. However shifting to these alternatives would result in the forfeiture of the significant benefits generated by the use of aldicarb.

Summary and Recommendations

Aldicarb is utilized for pest management in all of the cotton producing states. This pesticide has been effectively used as a granular formulation to control thrips, aphids, spider mites, whitefly, cotton leaf- perforator, lygus bugs, and leafhoppers. A major proportion of this use is at planting time and is directed against thrips, aphids, and to some extent, against spider mites. Applications of aldicarb against fleahopper are as both planting time and early fruiting stage sidedress applications. Sidedress applications during the fruiting stage of crop development are for control of lygus bugs, fleahoppers, cotton leafperforator and whitefly.

Aldicarb is used in anticipation of pest problems that may develop. This type of usage provides a degree of pest control assurance for production areas where outbreaks are relatively consistent. Utilization of a granular formulation placed in the soil reduces the probability of pesticide drift to adjacent areas and exposure of mixers/loaders and applicators to alternative toxicants.

Aldicarb is a broad spectrum toxicant that will destroy populations of several predacious arthropods when applied at the higher rates as a sidedress application. For that reason, treated fields should be monitored frequently for outbreaks of other pests or for reinvasion by targeted pests. In contrast, rates of aldicarb used in-furrow are not as detrimental to predaceous arthropods as alternate foliar sprays. Beneficial arthropods monitored in research in the mid-south and Texas included lady beetles, lacewings, big-eyed bugs, damsel bugs, minute pirate bugs and spiders. Populations in these trials were occasionally reduced in aldicarb-treated fields, but declines were usually temporary and less severe than fields sprayed with foliar insecticides (Scott, 1985; Ingram, 1979; Pendergrass, 1979; and Ridgway, 1967).

Like other pesticides, there is need to preserve the efficacy of aldicarb against resistance in target pests and to avoid an unnecessary environmental load. This product should be used in situations where there are consistent outbreaks of target pests and where well monitored pest situations indicate need for control.

There are alternatives to the use of aldicarb in controlling most of the pests previously described. Estimates of alternative pesticide usage against pests are summarized in Tables 49 and 50. In

the opinion of most experts who responded to the NAPIAP pesticide use questionnaire, the use of alternative controls would result in reduced yields and/or quality of cotton lint. In the South and southeastern United States, there would be more problems with weed control if alternatives were adopted. The cost of cotton production in the United States would increase if certain alternatives were used.

The aldicarb team is alarmed by the prospect of losing another insecticide for use on cotton through the registration process. Aldicarb is an effective IPM tool to control insect and nematode pests of cotton. Furthermore, cotton growers have an excellent safety record in terms of using aldicarb within the range of recommended rates. The benefits of aldicarb use on cotton outweigh the costs. We recommend the reregistration of all aldicarb uses on cotton by EPA. In turn we recommend against any pesticide use unless cotton fields have been monitored for pests and use of pesticide is certified to be necessary based on a recognized threat to production.

Table 46. Aldicarb use on cotton in the major cotton producing states

State	Target pest	Rate of application (lbs ai/A) At planting			Treated acres (x 1000)
		In-furrow	Band	Side dress	
Alabama	1,7,8	0.6			208.0
Arizona	1,2,4,7,8 2,3,4,7	.05		 1.0-3.0	41.4 41.4
Arkansas	1,7,8	0.45			289.3
California					
San Joaquin Valley	1,7,8,10 4,7	0.35-0.75		 1.0-2.0	298.8 130.4
Imperial Valley	4 3,4,5,7,9 3,5,7,9	0.45-0.75 0.45-0.75		 1.5-2.1 1.5-2.1	3.4 3.0 3.4
Florida	8 10	0.52	 1.8		6.2 1.1
Georgia	1,8,10	0.5			103.5
Louisiana	8,10	0.45-0.5			324.5
Mississippi	8	0.3-0.5			550.0
Missouri	1,8	0.35			120.0
New Mexico	1,7,8,10 1,4,7,8,10 4,7	0.35-0.75 0.35-0.75		 1.0-2.0 1.0-2.0	10.8 7.2 3.0
North Carolina	7,8	0.38			72.3
Oklahoma	2,8 10	0.4	 0.9		6.7 0.1
South Carolina	7,8 10	0.45	 1.2		79.1 5.3
Tennessee	1,7,8	0.6			62.5
Texas	8 10	0.38 0.53			1,432.9 144.1
Virginia	7,8	0.45			1.2
Total					3,949.6

*Pests are numbered as follows: aphids=1, cotton fleahopper=2, cotton leaf perforator=3, *Empoasca* spp.=4, *Lygus* spp.=5, Southern garden fleahopper=6, spider mites=7, thrips=8, whiteflies=9, and nematodes=10.

Table 47. Estimated reductions cotton yields resulting from damage by insects that would normally be controlled by aldicarb, 1983–87

Pest	1983		1984		1985		1986		1987		Total Bales lost	Avg. % Yield lost
	Bales lost	% Yield lost	Bales lost	% Yield lost	Bales lost	% Yield lost	Bales lost	% Yield lost	Bales lost	% Yield lost		
Cotton fleahopper	30.6	0.4	45.6	0.3	50.8	0.4	84.8	0.9	133.6	0.9	354.4	0.58
Lygus spp. & other plant bugs	54.7	0.7	177.2	1.3	101.6	0.7	79.0	0.8	37.4	0.3	449.9	0.76
Cotton leaf perforator	0.4	<0.1	0.7	<0.1	0.5	<0.1	1.9	<0.1	0.6	<0.1	4.1	<0.1
Spider mite	48.4	0.6	75.9	0.6	69.5	0.5	37.0	0.4	7.6	0.1	238.4	0.44
Thrips	29.1	0.4	30.8	0.2	91.5	0.7	26.6	0.3	18.3	0.1	196.3	0.34
Total	163.2	2.1	330.2	2.4	313.9	2.3	229.3	2.4	197.5	1.4	1,234 .1	2.12

*Bales x 1000. Estimates are from Reports of the Cotton Insect Loss Committee of the 37th Annual Conferences on Cotton Insect Research and Control.

Table 48. Insecticide/nematicide alternatives to the use of aldicarb

Alternative	Number of states reporting alternatives for pest control**								
	ap	fh	es	lf	ls	sm	th	wf	nm
acephate foliar	2	1			1		4	1	
acephate seed treatment	1						4		
azinphosmethyl			1						
carbofuran	1						5		
chlorpyriphos	1				2		1		
cypermethrin			1				1		
dicofol					3				
dicrotophos		1			1		5		
dimethoate	1	1			2		6		
disulfoton	4					1	10		
endosulfan								1	
ethyl parathion			1		2				
fenamiphos									1
fenvalerate					1				
malathion			1						
methamidophos	1				2			1	
methyl parathion							1		
monocrotophos							1		
naled					1				
permethrin			1	1					
oils (vegetable or mineral)								1	
oxamyl			1						
phorate	3					3	10		
phosphamidon									
profenofos				1					
propargite						3			
sulfur						3			
Telone II									2

*Source: Survey of state extension specialists and/or crop management specialists in November, 1988.
**Pests are indicated as follows: aphids=ap, fleahoppers=fh, *Empoasca* spp.=es, leaf perforator=lf, *Lygus* spp.=ls, spider mites=sm, thrips=th, whiteflies=wf, nematodes=nm

Table 49. Recommended dosages (lb ai/acre) of miticides for control of specific species of spider mites

Miticide	Species								
	Carmine	Desert	T. yustis	Pacific	Schoene	Strawberry	Tumid	Two-spotted	Ludeni
Aldicarb[1]	0.3–1.0	0.6–1.0	0.6–1.0	--	--	0.6–1.0	--	0.3–1.0	--
Carbophenothion	0.25–0.75	0.375–0.5	--	--	0.25–0.5	0.375	--	0.25–0.75	--
Chlorpyrifos	1.0	0.25–1.0	--	--	--	0.25–1.0	1.0	0.25–1.0	--
Demeton	0.25	0.25–0.375	0.375	0.375	0.375	0.375	0.25–0.375	0.375	[--]
Dicofol	1.0–1.5	0.8–1.6	--	0.8–1.0	--	0.8–1.6	--	0.8–1.6	--
Dicrotophos	0.25–0.5	0.25–0.5	0.25–0.5	--	--	0.25–0.5	--	0.25–0.5	--
Disulfoton[2]	0.5–1.0	0.5–1.0	--	--	--	0.5–1.0	--	0.5–1.0	[--]
Ethion	0.25–1.5	0.25–0.75	0.25–1.0	--	0.25–1.0	0.25–0.1	--	0.25–2.0	[--]
Methamidophos	0.5–1.0	--	--	--	--	--	0.5–1.0	0.5–1.0	[--]
Methidathion	1.0	1.0	1.0	1.0	1.0	1.0	--	0.5–1.0	[--]
Methyl parathion	--	0.6	--	--	0.6	--	0.6	0.6	[--]
Monocrotophos	0.2–1.0	0.25–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.5–1.0	0.2–1.0	0.2–1.0	0.5–1.0
Oxydemeton-methyl	0.25–0.5	0.25–0.5	0.25–0.5	0.25–0.5	0.25–0.5	0.25–0.5	0.2–0.5	0.25–0.5	0.25–0.5
Parathion	--	0.25–0.5	0.1–0.2	--	--	--	0.25–0.5	0.125–1.0	0.2
Phorate[3]	0.5–1.5	0.5–1.5	--	--	--	0.4–1.5	--	0.5–1.5	[--]
Propargite	1.0–1.25	--	--	0.8–1.6	--	0.8–1.6	--	0.5–1.6	[--]
Sulfur	--	25–30	--	--	--	25–35	--	20–50	[--]

[1]In-furrow granular treatment at planting.
[2]In-furrow granular treatment at planting or 0.5 pound per hundredweight of planting seed.
[3]In-furrow granular treatment at planting or 1.3 to 1.5 pounds per hundredweight of planting seed.
(From 37th Annual Conference Report on Cotton-Insect Research and Control. USDA ARS.)

Table 50. Estimated annual use of alternative treatments if aldicarb were no longer available*

State	Total** acres	Acres treated with aldicarb	At planting (disultoton or phorate)	Foliar	At planting+ foliar	Untreated
Alabama	320.0	208.0	0	124.8	83.2	0
Arizona	331.5	82.8	0	41.4	441.4	0
Arkansas	445.0	289.3	245.9	43.4	0	0
California						
San Joaquin Valley	1086.5	429.2	44.8	150.2	149.4	0
Imperial Valley	45.7	9.8	0	9.8	0	0
Florida	20.7	7.2	7. 2	0	0	0
Georgia	207.0	103.5	82.8	20.7	0	0
Louisiana	590.0	324.5	64.9	259.6	0	0
Mississippi	1100.0	550.0	110.0	440.0	0	0
Missouri	200.0	120.0	96.0	12.0	0	12.0
New Mexico	60.0	21.0	12.1	3.7	0	5
N. Carolina	85.0	72.3	53.5	18.8	0	0
Oklahoma	450.0	6.8	3.4	3.4	0	0
S. Carolina	105.4	84.3	42.2	29.5	0	12.7
Tennessee	338.0	62.5	0	62.5	0	0
Texas	4780.0	1,577.4	1,025.3	315.4	0	236.6
Virginia	1.477	1.247	.923	.324	0	0
Total	12,164,800					

*Source: Survey of state extension specialists and/or crop management specialists in 1988.
**Average acreages for 1983-1987.

Table 51. Annual economic benefits from use of aldicarb in U.S. cotton production

State	Total benefits ($)	Yield loss ($)	Quality reduction ($)	Pest control costs ($)	Other production cost ($)	Total benefits per treated acre ($/acre)	Total benefits divided by value of production
Alabama	12,036,617	5,522,190	600,238	1,754.189	4.160,000	37.87	0.09
Arizona	8,363,512	4,306,531	3,147,501	909,480		25.23	0.03
Arkansas	8,290,596	7,076,602	653,225	126,894	433,875	28.66	0.05
California							
San Joaquin	292,666	0		292,666		0.68	0.00
Imperial	272,248	0	373,972	-101,724		27.78	0.01
Florida	258,151	289,874		-31,723		35.85	0.03
Georgia	1,362,350	1,455,562		-93,212		13.16	0.02
Louisiana	12,150,886	11,635,142		191,244	324,500	37.44	0.06
Mississippi	25,331,405	22,484,385		2,847,020		46.06	0.06
Missouri	5,450,852	3,670,758	1,704,410	75,684		45.42	0.07
New Mexico	546,255	658,193		-111,938		26.01	0.03
North Carolina	1,861,489	1,334,937	226,864	-80,348	380,035	25.76	0.07
Oklahoma	136,442	128,877		7,565		20.07	0.00
South Carolina	2,506,445	1,693,081	699,526	-249,162	363,000	29.73	0.09
Tennessee	-73,375	0		-73,375		-1.17	0.00
Texas	10,198,038	17,565,059		-340,997		6.47	0.01
Virginia	28,088	20,635	3,696	-1,356	5,113	22.52	0.07
Total	89,012,666	70,815,802	7,409,433	5,120,907	5,666,552	25.15	0.04

Aldicarb Use on Peanut

Patrick M. Phipps

Peanut production is concentrated in three geographic areas of the United States: 1) the Southeast (Georgia, Florida and Alabama), 2) the Southwest (Texas, Oklahoma, and New Mexico), and 3) Virginia-Carolina (Virginia, North Carolina and South Carolina). Table 52 contains the average acreage, yield and value statistics for peanut in each state during the 5 year period from 1984-88. Approximately 66 percent of production was centered in the Southeast, 16 percent in the Southwest, and 18 percent in the Virginia-Carolina region. Each year, peanut was grown on approximately 1.5 million acres, yielded approximately 2 million tons, and had a market value of approximately $1 billion.

Registration Summary

Aldicarb is registered for at-plant application to the seed furrow for thrips control at rates of 1 to 2 pounds active ingredient (lb ai) per acre in rows spaced 36-inches apart (7.5 to 15 oz ai/1000 ft of row). The registered use pattern for nematode control is a 6- to 12-inch band of aldicarb at 2 or 3 lb ai/acre, or 15 to 22 oz ai/1000 ft of row, incorporated in soil to a depth of 2 to 4 inches in front of planters.

Pest Infestation and Damage

The dynamics of crop production environments and pests over time make it extremely difficult, if not impossible, to document or predict yield losses to target pests in peanut production. Changes in market prices, production quotas, and on-farm revenues from year-to-year are among the many factors which dictate planted acreages and the levels of input within a region. Scientific documentation of yield losses to target pests has not provided the necessary database for confidence in making an estimate of national losses to any given pest. For these reasons, only some selected examples of yield loss attributed to specific pests can be cited. The following examples reflect what may result when certain target pests are not controlled; however, it should be recognized that such examples are highly specific for pest population, location and weather conditions at the time of study.

Thrips: The direct effects of thrips damage on growth, yield and quality of peanut have been a subject of controversy for several decades. While the majority of reports (Smith, 1972; Tappan and Gorbet, 1981) and responses to the NAPIAP aldicarb questionnaire indicated little or no direct damage caused by thrips, most agriculturists agree that thrips control can provide significant indirect benefits to crop management and yield. The most important benefits were an accelerated rate of seedling growth in the first 30-days after planting, and a reduction in risk for thrips and aphid transmission of viruses such as peanut stunt virus, tomato spotted wilt virus, and peanut stripe virus (Porter et al., 1984; Lynch et al., 1988). Outbreaks of these viruses have been sporadic and/or somewhat localized in the United States, however, their potential to cause devastating losses of yields in peanut cannot be ignored.

Nematodes: Yield losses to nematodes in peanut production have been well documented in problem fields throughout the peanut production areas of the United States (Dickson and Waites, 1979; Hagan and Weeks, 1984, 1985, and 1986; Hagan, 1989; Phipps and Elliott, 1982 and 1984; Phipps, 1986; Wheeler and Starr, 1987). The principal kinds of nematodes causing economic losses of yield and quality have been the root-knot (*Meloidognyne arenaria, M. hapla*), lesion (*Pratylenchus brachyurus*), sting (*Belonolaimus spp.*), and ring (*Macroposthonia spp.*) (Porter et al., 1984). The distribution and occurrence of damaging numbers of nematodes in peanut soils varies considerably, however, yield-reducing infestations of one or more species are common in most production areas. Yield losses to root-knot nematode have been reported to range from 20 to 90 percent (Porter et al., 1984). Accurate predictions of yield loss to root-knot and other nematodes have been difficult, because of the significant interaction of nematode injury with other factors. Frequently, bacteria and fungi colonize damaged root and pod tissues and further reduce yield, quality, and value of the crop. Common examples are the increased incidence of pod rot, and root diseases such as cylindrocladium black rot.

Other Pests: Control and/or suppression of aphids, leafhoppers, and spider mites were included in the responses of state specialists concerning secondary benefits of aldicarb applications to peanut. The importance of aphids attacking peanut was related to their role as vectors of certain viruses. The potato leafhopper has been reported to cause foliage injury, and heavy infestations can cause significant reductions of yield. Spider mites are especially destructive to peanut during hot, dry weather and have been reported to cause considerable yield loss in some years.

Pest Management

Current Chemical Usage

In December 1988, a NAPIAP pesticide use questionnaire was sent to each of the 50 states and territories of the United States to determine aldicarb use patterns. Based on results of the survey, aldicarb is most commonly applied to the seed furrow or is soil incorporated in a band at planting time (Tables 53 and 54). An estimated 974,400 lb of aldicarb was utilized in production of peanut annually from 1984-88 (Table 54). About 46 percent (443,000 lb) of aldicarb applied to peanut was applied at planting to the seed furrow, and 46 percent (452,000 lb) was soil incorporated in a band at planting. The mid-season, pegging-time application accounted for approximately 8 percent (79,000 lb) of total aldicarb use on peanut.

Thrips and nematodes are the primary target pests of aldicarb applications to peanut according crop production specialists (Table 56). An at-plant application of aldicarb at 0.6 to 1 lb ai/acre in the seed furrow is commonly used in many peanut producing regions for control of thrips and suppression of nematodes (Tables 53 and 52). When nematode infestations are heavy, a soil incorporated band of aldicarb at 1.2 to 3 lb ai/acre is used at planting to achieve nematode control. Other use patterns which are less common include band applications over rows at pegging, and various combinations of planting time (in-furrow or band) and pegging applications. The pegging-time application is authorized in certain states (Florida, Georgia, North Carolina, Virginia, Oklahoma and Texas) under special local need 24(c) registrations for insect, nematode, and/or mite control. All states indicated the maximum cumulative dose with aldicarb in a growing season did not exceed 3 lb ai/acre.

Applications of aldicarb at planting have been observed to enhance early-season growth as a result of thrips control, early-season suppression of nematode injury, and possibly some unknown non-target effects. The in-furrow application of aldicarb at 0.6 to 1 lb ai/acre is generally considered superior to alternative insecticides for stimulation of early season growth. In Virginia and the panhandle area of Texas, the enhancement of early season growth is thought to be an important factor in early maturity and harvest to avoid frost damage (T.A. Lee and P.M. Phipps, personal communication). Several state specialists also indicated that enhanced early-season growth could be beneficial in suppression of weed growth between rows, and result in the elimination of an application of herbicide for weed control.

In Texas, thrips control is essential to suppress epidemics of tomato spotted wilt virus (R.L. Holloway and T.A. Lee, personal communication). This use-pattern for aldicarb or other insecticides may increase in future years, since the virus has been detected in peanut within the southeast region of the United States.

Chemical Alternatives for Pest Management

In response to the NAPIAP aldicarb questionnaire, crop management specialists considered alternative chemicals, not cultural practices, to be the primary alternatives to aldicarb for control of target pests (Table 57). Crop rotation was considered to have little or no practical value in control of both insects and nematodes. No commercially-accepted cultivars of peanut have resistance to thrips or other foliage feeders, or nematodes.

Granular formulations of disulfoton and phorate applied in-furrow at planting time were the most frequently cited as alternatives for control of thrips (Table 57).. Overall, disulfoton was projected as being the most favored treatment. Applications of foliar sprays of insecticides were generally considered a secondary option for thrips control, except for states of New Mexico, Oklahoma, and Texas. The common tendency for foliar applied insecticides to increase the probability for outbreaks of spider mites was a common reason for the preference to use a granular insecticide at planting. If no granular in-furrow insecticide were available, most states indicated that foliar sprays of acephate would be the most favored treatment.

Alternative options for nematode control included carbofuran, ethoprop, fenamiphos, and dichloropropene. Fenamiphos was listed by crop management specialists as the most favored replacement for aldicarb as a nematode control treatment (Table 57). Ethoprop and carbofuran were commonly listed as secondary choices to the use of fenamiphos. The use of dichloropropene was least attractive, because of the high cost of treatment and the required 7- to 10-day waiting period between soil treatment and planting as well as other specific requirements for effective performance (Hagan, 1989). Fenamiphos would likely be the most heavily used alternative to aldicarb for nematode control, assuming an adequate supply of product was made available.

In comparison to alternative chemicals, aldicarb is unique in that common use patterns control both thrips and nematodes. In general, all of the alternative chemicals provide efficient control of either thrips or nematodes, but not both pests; a single application of aldicarb provides control of both pests. For this reason, the selection of chemical alternatives to aldicarb would commonly require separate applications of more than one product.

Economic Impacts Caused by Aldicarb Loss

Based on the questionnaire responses of state specialists, estimates were developed for the use of aldicarb and the alternative chemicals if aldicarb were no longer available for application to peanut to control thrips and nematodes (Tables 58 and 59). The cost of using aldicarb and alternative chemicals to control these pests was computed on the basis of rates specified by state specialists, application costs, and standard product prices (B.Y. Mason, 1989). Except for New Mexico and Texas, state specialists indicated that the use of either disulfoton or phorate could provide effective thrips control at near one-half the cost of aldicarb (Table 60). A major limitation with these products as well as foliar applied insecticides was a total lack of nematode control and suppression of spider mites. For nematode control, the overall costs of using either aldicarb or fenamiphos were similar (Table 61). Both products were cheaper than 1,3-D, but more expensive than carbofuran or ethoprop. All of the alternatives to aldicarb for nematode control were considered ineffective for control of thrips and lacked any benefit in suppression of spider mites.

The economic analysis of aldicarb use and its benefits was then focused on changes in peanut production costs, and changes in yield and market value of the crop as a result of the substitution of alternative chemicals for aldicarb. All of the alternatives to aldicarb for thrips control alone would result in reduced production costs with the exception of acephate in Alabama and Texas, and carbaryl in Alabama (Table 62). Overall, the use of alternatives to aldicarb for thrips control would reduce total production costs for peanut in the United States an estimated $2.8 million. The cost of nematode control would increase an estimated $1 million nationally where 1,3-D is substituted for aldicarb (Table 63). However, the projected use of other alternatives (carbofuran, ethoprop, fenamiphos) for nematode control would more than offset this cost on a national basis.

The major impacts caused by the loss of aldicarb for peanut production are associated with changes in yield and market quality. National production of peanut would be reduced an estimated 20,150 tons with substitution of alternative chemicals for aldicarb to control thrips and nematodes. According to state specialists, the combined effects of changing to the alternatives of aldicarb for thrips and nematode control will reduced the dollar value of peanut production an estimated $13.1 and $3.6 million, respectively (Tables 64,65), for a total of $16.7 million.

The impact of using chemical alternatives to aldicarb for thrips and nematode control was determined by combining the changes in production cost and crop value without any adjustment in peanut acreage. These estimates indicated annual losses of $10.3 and $3.4 million as a result of changes associated with thrips and nematode control, respectively (Tables 66, 67). To maintain supplies of peanut near current quota levels set by the government, an additional 15,500 acres of harvested peanut acreage would be necessary at a cost of approximately $625 per acre for a total annual investment of approximately $9.7 million.

Summary and Recommendations

The cancellation of aldicarb use for thrips and nematode control in peanut would reduce the income of growers by $13.7 million (Table 68). An additional investment of $9.7 million would be required annually to provide the harvested acreage for maintaining production quotas (Table 68). Assuming supplies of alternative products were available for the transition and that additional land

were available to increase the acreage, the cost of making the transition to alternatives of aldicarb would total $23.4 million in the first year.

Based on the results of this assessment, the use of aldicarb for insect and nematode control in peanut has significant benefit to growers and to the competitive position of U.S. peanut in world markets. This registration should be maintained, provided significant environmental and health hazards can be managed at acceptable levels. According to crop management specialists, the drinking water well set-back restriction of 50 feet for aldicarb application to peanut would have little effect on current use patterns. Since peanut is generally not planted when soils in the treatment zone are below 65 °F, a restriction on aldicarb use at temperatures below 50 °F would have no impact on peanut production.

Table 52. Annual statistics for peanut production in the United States, 1984-88*						
State	Planted acres	Harvested acres	Total yield (tons)	Yield/acre (lb)	Value ($)	($/lb)
Alabama	219200	217800	276474	2539	148667	.269
Florida	89000	81200	114626	2823	58307	.254
Georgia	647600	642600	910415	2834	490390	.269
New Mexico	13100	13100	15968	2438	9852	.308
North Carolina	152400	150600	215488	2862	120455	.279
Oklahoma	95800	91000	99014	2176	55047	.278
South Carolina	13200	13000	16228	2497	8329	.257
Texas	244600	238000	203242	1708	94092	.231
Virginia	93200	92600	134524	2905	69222	.257

*Source: Crop Production and Crop Value. USDA, National Agricultural Statistics Service, Jan. 1986, 87, 89.

Table 53. Percent of U.S. peanut acreage treated with aldicarb, 1984-88*						
State	Furrow (at plant)	Band (at plant)	Pegging (Band)	Furrow + Band	Furrow + Pegging	Band +Pegging
Alabama	40	25	--	--	--	--
Florida	20	3	3	--	--	6
Georgia	20	12	--	--	--	4
New Mexico	5	--	--	--	--	--
North Carolina	78	2	<1	3	<1	--
Oklahoma	15	2	1	--	--	1
South Carolina	70	10	--	--	--	--
Texas	22	5	--	--	7	--
Virginia	65	8	<1	5	<1	<1

* Source: survey of state pesticide coordinators and/or their designated extension specialists in December 1988, and subsequent personal communications.

Table 54. Rates and use patterns for aldicarb on peanut in the United States, 1984-88*						
State	Furrow (at plant)	Band (at plant)	Pegging (Band)	Furrow + Band	Furrow + Pegging	Band + Pegging
Alabama	0.75	2.00	--	--	--	--
Florida	1.00	2.50	1.50	--	--	1.5 + 1.5
Georgia	0.75	3.00	--	--	--	1.5 + 1.5
New Mexico	1.00	--	--	--	--	--
North Carolina	1.00	2.50	--	1 + 1.5	--	--
Oklahoma	1.00	1.50	1.50	--	--	1 + 1.5
South Carolina	0.60	2.50	--	--	--	--
Texas	0.75	1.00	--	--	0.75 + 1.5	--
Virginia	1.00	2.00	1.00	1 + 1.5	1 + 1	2 + 1

* lb ai/acre. Source: Survey of state pesticide coordinators and/or their designated extension specialists in December 1988,and subsequent personal communication.

Table 55. Estimated annual amounts of aldicarb applied to peanut in the United States, 1984-88*						
State	Furrow (at plant)	Band (at plant)	Pegging (band)	Furrow +band	Furrow +pegging	Band +pegging
Alabama	65.7	109.6	--	--	--	--175.3
Florida	17.8	6.7	4.0	--	--	16.044.5
Georgia	97.1	233.1	--	--	--	77.7407.9
New Mexico	0.7	--	--	--	--	--0.7
North Carolina	118.9	7.6	--	11.4	--	--137.9
Oklahoma	14.4	2.9	1.4	--	--	2.421.1
South Carolina	5.5	3.3	--	--	--	--8.8
Texas	40.4	12.2	--	--	38.5	--91.1
Virginia	60.6	14.9	--	11.6	--	--87.1
Total	421.1	390.3	5.4	23.0	38.5	96.1974.4

*Total lb ai X 1000. Source: Survey of state pesticide coordinators and/or their extension specialists in December 1988, and subsequent personal communications.

Table 56. Target pests for various applications of aldicarb used on peanut in the United States, 1984-88*

State	Furrow (at plant)	Band (at Plant)	Pegging (band)	Furrow +band	Furrow +pegging	Band +pegging
Alabama	T[a]	N	--	--	--	--
Florida	T,H	T,N	N	--	--	T,H,N
Georgia	T,A,M	N	--	--	--	N
New Mexico	T	--	--	--	--	--
North Carolina	T,H,A,N	N	--	N	--	--
Oklahoma	T	N	N	--	--	N
South Carolina	T,N	T,N	--	--	--	--
Texas	T,N,TSW	T,N	--	--	T,N,TSW	--
Virginia	T,N,M	T,N,M	M,N,H	T,N,M	T,N,M,H	T,N,M.H

[a]T=thrips, H=leafhopper, A=aphids, N=nematodes, M=spider mites, TSW=tomato spotted wilt virus.
*Source: Survey of state pesticide coordinators and/or their designated specialists in December 1988, and subsequent personal communication.

Table 57. Insecticides and nematicides named as alternatives to use of aldicarb on peanut in the United States*

Chemical	Number of States Reporting Alternative Use			
	Thrips	Leafhoppers	Spider Mites	Nematodes
acephate	3	-	-	-
carbaryl	2	-	-	-
disulfoton	8	3	1	-
phorate	7	2	1	-
malathion	1	-	-	-
parathion	1	-	-	-
monocrotophos	-	-	1	-
propargite	-	-	1	-
carbofuran	2	1	-	6
ethoprop	-	-	-	5
fenamiphos	1	-	-	8
dichloropropene	-	-	-	4

*Source: Survey of state pesticide coordinators and/or crop management specialists in December 1988, and subsequent personal communication.

Table 58. Estimated use of alternative chemicals if aldicarb were no longer available for application to peanut for thrips control*

State	Chemicals and acres treated						
	Aldicarb	Acephate	Carbaryl	Disulfoton	Phorate	Parthion	Malathion
Alabama	42480	42744	2850	71240	14248	0	0
Florida	25810	0	0	1291	1549	0	0
Georgia	233136	0	0	186509	34970	0	0
New Mexico	655	655	0	0	0	0	0
North Carolina	126492	0	0	31623	94869	0	0
Oklahoma	17244	0	1724	0	0	13795	1724
South Carolina	10560	0	0	3696	3696	0	0
Texas	83164	62373	0	20791	0	0	0
Virginia	72696	0	7270	29078	14539	0	0

*Source: Survey of state pesticide coordinator and/or other designated extension specialists in December 1988, and subsequent personal communications.

Table 59. Estimated use of alternative chemicals if aldicarb were no longer available for application to peanut for nematode control*

State	Chemical and Acres Treated				
	Aldicarb	Carbofuran	Ethoprop	Fenamiphos	dichloropropene
Alabama	21920	1096	1096	17536	2192
Florida	10680	641	4165	8117	0
Georgia	103616	0	0	98435	5181
New Mexico	0	0	0	0	0
North Carolina	7620	381	1143	6096	0
Oklahoma	3832	0	958	2874	0
South Carolina	1320	396	0	396	0
Texas	29352	0	0	17411	17611
Virginia	12116	3635	3635	4846	0

*Source: Survey of state pesticide coordinators and/or their designated specialists in December 1988, and subsequent personal communications.

Table 60. Estimated cost ($/acre) of pest control with aldicarb and alternative chemicals for thrips control*

State	Aldicarb	Acephate	Carbaryl	Desulforon	Phorate	Parathion	Malthion
Alabama	11.90	13.73	12.56	6.00	6.15	-	-
Florida	15.87	-	-	9.00	6.15	-	-
Georgia	11.90	-	-	4.50	4.61	-	-
New Mexico	15.87	11.23	-	-	-	-	-
North Carolina	15.87	-	-	6.00	6.15	-	-
Oklahoma	15.87	-	6.28	6.00	4.61	4.63	5.00
South Carolina	9.52	-	-	6.00	5.54	-	-
Texas	11.90	36.19	16.34	-	-	-	-
Virginia	15.87	-	6.28	6.00	4.61	-	-

* Based on state estimates of rate, number of applications, and product cost.

Table 61. Estimated cost ($/acre) of pest control with aldicarb and alternative chemicals for nematode control*

State	Aldicarb	Carbofuran	Ethoprop	Fenamiphos	Dichloropropene
Alabama	31.74	26.19	18.75	32.24	67.93
Florida	39.68	17.46	18.75	32.24	-
Georgia	47.61	-	-	35.83	67.93
New Mexico	-	-	-	-	-
North Carolina	31.74	26.19	18.75	31.53	-
Oklahoma	23.81	-	18.75	35.83	-
South Carolina	39.68	26.19	-	35.83	-
Texas	20.63	-	-	35.83	67.93
Virginia	28.57	21.83	15.63	35.83	-

* Based on state estimates of product rate and application cost.

Table 62. Change in total production cost of peanut with the use of chemical alternatives to aldicarb for thrips control*

State	Acephate	Carbaryl	Disulfoton	Phorate	Parathion	Malathion	Total
Alabama	78115	1874	-420494	-81962	-	-	-422,467
Florida	-	-	-8866	-15052	-	-	-23,918
Georgia	-	-	-1380631	-254934	-	-	-1,635,566
New Mexico	-3039	-	-	-	-	-	-3,039
North Carolina	-	-	-312119	-922127	-	-	-1,234,246
Oklahoma	-	-16537	-	-	-155066	-18746	-190,349
South Carolina	-	-	-13017	-14736	-	-	-27,753
Texas	1514884	-	-247465	-	-	-	1,267,419
Virginia	-	-69715	-287004	-163675	-	-	-520,394
Total	1,589,960	-84,379	-2,669,596	-1,452,486	-155,066	-18,746	-2,790,313

Based on state estimates of acres to be treated and cost of treatment in comparison to aldicarb. Minus values reflect a reduction in cost.

Table 63. Change in total production cost of peanut with the use of chemical alternatives to aldicarb for nematode control					
State	Carbofuran	Ethoprop	Fenamiphos	Dichloropropene	Total
Alabama	-6,083	-14,237	8,812	79,333	67,825
Florida	-14,235	-87,157	-60,328	-	-161,720
Georgia	-	-	-1,160,059	105,284	-1,054,775
New Mexico	-	-	-	-	-
North Carolina	-2,115	-14,848	-1,305	-	-18,267
Oklahoma	-	-4,843	34,545	-	29,703
South Carolina	-5,340	-	-1,525	-	-6,865
Texas	-	-	178,390	833,027	1,011,417
Virginia	-24,502	-47,038	35,180	-	-36,360
Total	-52,275	-168,122	-966,289	1,017,644	-169,042

*Based on state estimates of acres treated and cost of treatment in comparison to aldicarb. Minus values reflect a reduction in cost.

Table 64. Change in dollar value of the peanut crop with the use of chemical alternatives to aldicarb for thrips control

State	Acephate	Carbaryl	Disulfoton	Phorate	Parathion	Malathion	Total
Alabama	0	0	0	0	–	–	–
Florida	–	–	0	0	–	–	–
Georgia	–	–	0	-2664155	–	–	-2,664,155
New Mexico	-4293	–	–	–	–	–	-4,293
North Carolina	–	–	-729933	-729933	–	–	-1,459,865
Oklahoma	–	-65579	–	–	-948369	-65579	-1,079,526
South Carolina	–	–	-49619	-49619	–	–	-99,237
Texas	-7121622	–	0	–	–	–	-7,121,622
Virginia	–	0	-45307	-227154	–	–	-681,461
Total	-7,125,915	-65,579	-1,233,858	-3,670,860	-948,369	-65,579	-13,110,160

*Based on state estimates of acres treated, mean yield/acre, and changes in yield and market quality. Minus values reflect a reduction in value.

Table 65. Change in dollar value of the peanut crop with the use of chemical alternatives to aldicarb for nematode control*

State	Carbofuran	Ethoprop	Fenamiphos	1,3-D	Total
Alabama	-187,028	-239,396	- 1,795,471	0	-2,221,896
Florida	-50,301	-358,818	-616,130	-	-1,025,249
Georgia	-	-	0	0	0
New Mexico	-	-	-	-	-
North Carolina	-13,003	-52,766	0	-	-65,769
Oklahoma	-	0	0	-	0
South Carolina	-2,703	-	0	-	-2,703
Texas	-	-	0	0	0
Virginia	-124,053	-141,971	0	-	-266,024
Total	-377,089	-792,952	-2,411,601	-	-3,581,642

*Based on state estimates of acres treated, mean yield/acre, and changes in yield and market quality. Minus values reflect a reduction in value.

Table 66. Annual economic impact of substituting alternative chemicals for aldicarb for thrips control in peanut production *

State	Acephate	Carbaryl	Disulfoton	Phorate	Parathion	Malathion	Total
Alabama	-78,115	-1,874	420,494	81,962	–	–	422,467
Florida	–	–	8,866	15,052	–	–	23,918
Georgia	–	–	1,380,631	-2,409,221	–	–	1,028,590
New Mexico	-1,254	–	–	–	–	–	-1,254
North Carolina	–	–	-417,814	192,194	–	–	-225,619
Oklahoma	–	-49,042	0	–	-793,302	-46,833	-889,177
South Carolina	–	–	-36,601	-34,883	–	–	-71,484
Texas	-8,636,506	–	-247,465	–	–	–	-8,389,041
Virginia	–	69,715	-167,303	-63,479	–	–	-161,066
Total	-8,715,875	18,800	1,435,738	-2,218,374	793,302	-46,833	-10,319,846

* Based on estimates of changes in crop value and production costs. Minus values reflect a reduction of grower income.

Table 67. Annual economic impact of substituting chemical alternatives to aldicarb for nematode control on peanut*

State	Carbofuran	Ethoprop	Fenamiphos	Dichloropropene	Total
Alabama	-180,945	-225,159	-1,804,283	-79,333	-2,289,721
Florida	-36,066	-271,662	-555,802	-	-863,529
Georgia	-	-	1,160,059	-105,284	1,054,775
New Mexico	-	-	-	-	-
North Carolina	-10,889	-37,919	1,305	-	-47,503
Oklahoma	-	4,843	-34,545	-	-29,703
South Carolina	2,637	-	1,525	-	4,162
Texas	-	-	-178,390	-833,027	-1,011,417
Virginia	-99,551	-94,933	-35,180	-	-229,664
Total	-324,814	-624,830	-1,455,312	-1,017,644	-3,412,600

* Based on estimates of changes in crop value and production costs. Minus values reflect a reduction of grower income.

Table 68. Summary of economic benefits analysis for aldicarb in peanut production

Economic Factor	Dollar Impact
Thrips control	-$10,319,846
Nematode control	-3,412,600
Acreage increase	-9,687,500
Total	-$23,419,946

Aldicarb Use on Soybean

William S. Gazaway

Harvested soybean (*Glycine max*) acreage has declined over the past 5 years from 66.1 million acres (1984) to 58 million acres (1987) as a result of low soybean prices (Table 69). With the return of more favorable prices in 1988, soybean acreage increased slightly to 58.9 million acres with a market value of $11 billion. Most U.S. soybean production is concentrated in the Midwest, where 9 states account for over 62 percent of total acreage. The Southern and Southeast-Atlantic states account for a vast majority of remaining U.S. soybean production (Table 70).

Registration Summary

Aldicarb is registered as an at-planting soil applied treatment for the control of nematodes and Mexican bean beetle, and suppression of thrips. Aldicarb is registered at rates from 0.75 to 1.5 pounds active ingredient (lb ai) per acre (36-inch row spacing) as an in-furrow treatment for insect and nematode control. Higher rates (1.5 to 3 lb ai/acre) are used solely for nematode control; these treatments are incorporated in a 6- to 8-inch band over the row.

Pest Infestation and Damage

Nematodes: Nematodes are the primary target pests for aldicarb applications on soybean (Table 72). Several nematode species attack soybean, but the soybean cyst nematode (*Heterodera glycines*) is the most damaging and widespread. Root-knot nematodes (*Meloidogyne* spp.) rank second in importance to the cyst nematode in terms of damage. Except for the northern root-knot nematode (*Meloidogyne hapla*), nematode problems are confined generally to the southern-most soybean producing areas in the United States. Other nematodes of less importance include the sting nematode (*Belonolaimus* sp.), reniform nematode (*Rotylenchulus reniformis*) and lance nematode (*Hoplolaimus galeatus*).

Yield losses caused by nematode infestation are difficult to document due to varied growing and environmental conditions from year-to-year. Documented yield losses range from 5 to 100 percent (Kinloch, 1982; Rodriguez-Kabana et al., 1981).

Insects: Insects such as thrips (*Franklinella fusca, F. occidentalis, Thrips tabaci, Sericothrips variabilis*), Mexican bean beetle (*Epilachna varivestis*) and three-cornered alfalfa hopper (*Spissistilus festinus*) cause occasional problems on soybean in some states. However, insect damage is sporadic and is far less serious than nematode damage.

Pest Management

Aldicarb is the most widely used insecticide/nematicide applied to the small percentage of U.S. soybean that is treated with pesticides. The responses of extension and research personnel to the 1988 NAPIAP pesticide use questionnaire indicate that 10 of 29 soybean producing states use aldicarb on soybean (Table 71). Approximately 333,300 lb of aldicarb were applied to 237,500

planted acres in those states. This represents less than 0.4 percent of total U.S. soybean acreage (Table 71). The producers in a majority of states use band applications of aldicarb to provide a larger zone of protection in the soil against nematodes than that provided by in-furrow application (Table 72). Only 3 states favored the in-furrow method for nematode control. Conversely, for insect control, most respondents indicated a preference to place systemic aldicarb in the seed furrow to permit easier uptake by the plant.

Aldicarb can reduce early-season nematode populations in the soil (Rodriguez-Kabana et al., 1981; Kinloch, 1982). However, aldicarb does not reduce nematode populations for an entire growing season. By the end of the growing season, nematode populations in aldicarb treated areas are often as large or even exceed nematode populations in untreated areas. The primary intent, therefore, is to use aldicarb to reduce early season nematode populations and allow the soybean plant to develop a strong root system and improve soybean yields. Yield responses from the use of aldicarb have been inconsistent based on experiments conducted in the soybean growing areas of the United States. Results of these tests can be grouped into four categories:

I. Several studies from field trials where aldicarb was applied to nematode infested fields either were inconclusive or indicated small or no yield increases (Bergeson and Elliott, 1982; Hershman et al., 1986; Hussey et al., 1983; Kinloch, 1982; Schmitt, 1989). This was the most commonly occurring result even where nematode populations were high.

II. The second most common result from field trials showed yield responses with the use of aldicarb in nematode infested fields, but the magnitude of these responses was insufficient to recover the basic production and nematicide costs. This situation occurred frequently in soybean fields which yielded less than 20 bushels per acre. In these fields relatively large yield increases (6-15 bushels) failed to cover basic production costs, nematicide costs, and return a profit (Bergeson, 1981; Mueller, 1985, 1988; Stuckey et al., 1984).

III. In a few soybean growing areas profitable yield responses were reported with the application of aldicarb to nematode infested fields that routinely produced more than 25 bushels per acre. In Tennessee, Chambers (1985 and 1988) realized an economic benefit from aldicarb use with a 5 to 6 bushel/acre increase. In Virginia, Phipps et al. (1983, 1988, and 1989) reported similar results (6 to 7 bushel/acre increases) applying aldicarb as an in-furrow treatment.

IV. In a few cases, substantial yield responses were observed where aldicarb was applied in fields with mixed root-knot and soybean cyst nematode populations. Rodriguez-Kabana (1980) reported profitable returns from aldicarb applications in combination with soybean cyst resistant cultivars.

Carbofuran and fenamiphos are the two most commonly used alternatives to aldicarb. Five states indicated that a relatively small percentage (5-50 percent) of the acreage currently treated with aldicarb would switch either to carbofuran or fenamiphos. A sixth state indicated that carbofuran would be the exclusive replacement choice. Two other states, primarily interested in insect control, indicated they would switch to chlorpyrifos, disulfoton, and phorate (Table 73).

Non-Chemical Management Alternatives

Crop rotation and the use of nematode-resistant soybean cultivars are the most common alternatives to aldicarb. All 10 aldicarb-using states would use these two cultural practices on most of the acreage currently treated with aldicarb if aldicarb were no longer available (Table 73).

Economic Impacts

The effect on soybean yield caused by the loss of aldicarb would depend on which alternative treatments were used as replacements. Yield would be significantly lower if carbofuran and ethoprop were used, but yield would not be affected if dichloropropene and fenamiphos were used (Table 75). Crop rotation and the use of resistant soybean cultivars may significantly increase yield by approximately 9 bu/acre. The use of these two cultural practices would increase crop value by approximately $6 million nationwide (Table 75).

Changing to alternative nematicides would reduce farm income. The use of fenamiphos would cost producers an additional $259,800 compared to aldicarb (Table 76). Since the increase in yield would increase crop value $169,200 (Table 75), producers would realize a net loss of approximately $90,000. The use of dichloropropene would result in a net loss of $2,100 (Tables 75 and 76). A switch to carbofuran or ethoprop would save farmers $65,720 and $33,750 in material costs, respectively (Table 76). When application costs and lost yield are considered, U.S. soybean producers would lose approximately $353,896 by switching to carbofuran and $118,530 by switching to ethoprop (Tables 75 and 76).

The benefit of increased use of crop rotation and resistant cultivars is difficult to assess. Factors such as duration, crop selection, and availability nematode-resistant cultivars would vary according to the numbers and kinds of nematodes in individual fields. Consequently, no attempt is made in this report to determine costs of this practice. It is estimated that these cultural practices would increase soybean yield by as much as 9 bu/acre. A corn/soybean rotation would be a primary option for full-season soybean production.

Summary

The economic benefits attributable to the use of aldicarb and alternative chemicals for nematode control on soybean are questionable. This is reflected by the fact that relatively little aldicarb is still used in the United States. A loss of $5.4 million due to the use of aldicarb on soybeans was estimated but not included as a part of the total benefit in Table 70 and in the executive summary because it would detract from the positive benefits of use on other crops.

Crop rotation and the use of resistant soybean cultivars may be the most effective methods of controlling nematodes, particularly soybean cyst nematode (Kinloch, 1980; Rodriguez-Kabana et al., 1980). These cultural practices may be less effective for control of root-knot, reniform, lance, and sting nematodes. However, cultural practices may not be practical for some soybean producers. Producers who have limited land resources or farm on rented land cannot rotate their fields freely. Also nematode-resistant soybean cultivars may not be available for certain kinds of nematodes or may not be well suited to a production region. Aldicarb use may be economically justified in these cases. However, aldicarb use cannot be justified on a large percentage of U.S. soybean acreage.

Table 69. Soybean production in the United States, 1984-88*

Year	Acres harvested (million)	Total production (million bu)	Average price ($/bu)	Total value ($ million)
1984	66.1	1860.9	5.85	10,886.3
1985	61.6	2098.5	5.05	10,597.4
1986	60.4	1940.1	5.46	10,592.9
1987	58.0	1922.8	4.65	8,941.0
1988	58.9	1538.7	7.21	11,094.0

*Source: Crop Production and Crop Value. USDA, National Agricultural Statistics Service, Jan. 86, Jan. 89.

Table 70. Soybean five year production average by state, 1984-88*

State	Acres planted (x1000)	Acres harvested (x1000)	Average production (bu/acre)	Total production (1000 Bushels)
Alabama	844	812	22.9	18,556
Arkansas	3550	3470	22.3	83,390
Delaware	244	238	24.6	5,850
Florida	193	180	25.2	4,532
Georgia	1376	1210	21.4	25,848
Illinois	8990	8884	35.8	318,426
Indiana	4380	4322	36.2	156,387
Iowa	8240	8180	37.1	303,325
Kansas	1850	1770	27.5	48,669
Kentucky	1180	1136	30.0	33,623
Louisiana	2046	1956	24.1	47,115
Maryland	426	416	12.7	5,276
Michigan	1124	1100	30.5	33,510
Minnesota	4950	4868	32.9	160,364
Mississippi	2710	2594	22.1	57,293
Missouri	5090	4968	29.2	144,850
Nebraska	2460	2414	33.0	79,717
New Jersey	118	116	30.4	3,527
North Carolina	1632	1554	24.9	38,652
North Dakota	599	581	25.9	15,074
Ohio	3850	3788	36.5	138,396
Oklahoma	249	222	21.6	4,792
Pennsylvania	182	177	34.1	6,027
South Carolina	1076	1014	20.1	20,392
South Dakota	1438	1416	28.1	39,836
Tennessee	1514	1176	32.6	38,386
Texas	284	253	26.9	6,802
Virginia	640	614	25.7	15,810
Wisconsin	384	356	31.6	11,240
U.S. total	61,619	59,785		1,925,450

*Source: Crop Production. USDA, National Agricultural Statistics Service, Jan. 86, Jan. 89.

Table 71. Estimated amounts of aldicarb applied to soybean at planting in the United States

State	In-Furrow			Band			Grand Total Aldicarb (lb ai)
	Acres (x 1000)	Aldicarb lb ai/acre*	Aldicarb (lb ai)*	Acres (x 1000)	Aldicarb lb ai/acre*	Aldicarb (lb ai)	
Alabama	0	0	0	2.9	1.5	4.3	4.3
Arkansas	0	0	0	35.0	1.5	52.5	52.5
Illinois	5.0	1	5.0	0	0	05	.0
Iowa	0	0	0	80.0	2	160.0	160.0
Kentucky	13.0	1	13.0	11.8	2	23.6	36.6
Mississippi	5.0	1	5.0	0	0	0	5.0
N. Carolina	50.0	0.5	25.0	12.0	1.5	18.0	43.0
S. Carolina	0	0	0	10.8	1.5	16.2	16.2
Tennessee	5.0	1	5.0	0	0	0	5.0
Virginia	6.4	.75	4.8	.6	1.5	0.9	5.7
U.S. total	84.4		57.8	153.1		275.5	333.3

*Expressed in pounds active ingredient x1000. Source: Survey of state pesticide coordinators and/or extension specialists in December 1988.

Table 72. Target pests and method of application for aldicarb use at planting on soybean in the United States*

State	In-furrow*	Band
Alabama		N
Arkansas		N
Illinois	N	
Iowa		N
Kentucky		N,M,B
Mississippi	LCB	N
North Carolina	I	N
South Carolina		N,I
Tennessee	N	
Virginia	N,I	N,I

B=Mexican Bean Beetle, LCB=Lesser Cornstalk Borer, I=Insects (general), N=Nematodes. *In-furrow (0.5 lb ai/acre) treatment used for plant growth regulator effect also. Source: Survey of state pesticide coordinators and/or designated specialists in December, 1988.

Table 73. Alternatives to aldicarb for pest control on soybean in states which currently use aldicarb*

Alternative	Number of states reporting alternatives for pest control	
	Insects	Nematodes
crop rotation		10
resistant cultivars		10
carbofuran	2	6
fenamiphos		5
ethoprop		3
dichloropropene		2
chlorpyrifos	1	
disulfoton	1	
phorate	1	

*Source: Survey of pesticide cooperators and/or designated specialists in December, 1988.

Table 74. Estimated acreage (x 1000) that would be treated with an alternative practice if aldicarb were no longer available in states currently using aldicarb

State	Current aldicarb treated acreage	Acreage that would change to other practices				
		Dichloropropene	Carbofuran	Ethoprop	Fenamiphos	Resistant cultivars/ rotation
Alabama	2.9	0.3				2.6
Arkansas	35.0		17.5		17.5	
Illinois	5.0					5.0
Iowa	80.02	4.0	4.0	0.8	71.2	
Kentucky	24.8		0.2	0.2	0.2	24.2
Mississippi[1]	5.0					5.0
North Carolina[2]	62.0				3.0	59.0
South Carolina	10.8		2.7		2.2	5.9
Tennessee[3]	5.0		N.A.			5.0
Virginia	7.0		0.4	0.3	6.3	0
Total acres	237.5	0.3	24.8	4.5	30.0	117.9

[1]Lesser cornstalk borer the target pest.
[2]Only acreage treated for nematodes included in the estimate for alternative pesticide acreage.
[3]Did not provide acreage estimate.
[4]Source: Survey of state pesticide coordinators and/or extension specialists in December 1988.

Table 75. Value of soybean yield changes associated with the substitution of alternative controls for aldicarb

	Chemical alternatives				
	Dichloropropene	Carbofuran	Ethoprop	Fenamiphos	Resistant cultivars/ rotation
Yield change (bu/acre)*	0	-3	-6	+1	+9
Acres	300	24,800	4,500	30,000	117,900
Total change (bu)	0	-74,400	-27,000	30,000	1,061,100
Average price ($/bu)	5.64	5.64	5.64	5.64	5.64
Value ($)	0	-419,616	-152,280	169,200	5,984,604
Total for chemical alternatives = $402,696					
Total for resistant cultivars/crop rotation = $5,984,604					

There estimates are gross benefits and do not consider any possible reductions in revenue in years when soybean are not planted.
Total Value of Yield Changes with gross benefits of rotation: +5,581,908.
*Source: Survey of state pesticide coordinators and/or extension specialists in December 1988.

Table 76. Value of soybean pest control changes associated with the substitution of alternative controls for aldicarb

	Dichloropropene	Carbofuran	Ethoprop	Fenamiphos	Resistant cultivars/ rotation
Per acre control costs ($/acre)	27	17.35	12.5	28.66	-
Aldicarb control costs ($/acre)	20	20	20	20	-
Difference in control costs ($/acre)	7	-2.65	-7.5	8.66	-
Acres	300	24,800	4,500	30,000	-
Total value ($)	2,100	-65,720	-33,750	259,800	-

Total value of pest control cost changes: $162,430. Value does not include an estimate of cost associated with crop rotation.

Aldicarb Use on Tobacco

Paul J. Semptner

Tobacco (*Nicotiana tabacum* [L.]), the sixth largest cash crop in the United States, was harvested from 601,700 acres with a farm value of over $1.9 billion in 1987 (The Tobacco Institute, 1988). Over a 4-year period (1983-87), tobacco was grown annually on approximately 690,000 acres, with a production of 1.4 billion pounds and a value of $2.4 billion (USDA, 1988a). During this period, tobacco accounted for 1 percent of cash receipts from all farm commodities produced in the United States and 6 percent of cash receipts from farm commodities in the 16 leading tobacco producing states (USDA, 1988c). More than 93 percent of U.S. tobacco production occurs in 7 states: North Carolina, Kentucky, Tennessee, Virginia, South Carolina, Georgia, and Maryland. Since reaching a low in 1986, tobacco acreage has increased steadily and another sizable increase is predicted for 1989 (USDA, 1988b). This increase is the result of dwindling reserves and increased foreign demand for U.S. tobacco despite a steady decrease in domestic consumption. Between 1983 and 1987, tobacco exports from the United States averaged 609 million pounds annually, while total production averaged 1.4 billion pounds (USDA, 1988b).

Flue-cured tobacco, the most important tobacco type produced in the United States, is grown in Florida, Georgia, Alabama, South Carolina, North Carolina and Virginia (Table 77). Flue-cured tobacco production in North Carolina and Virginia accounted for 22 and 9 percent, respectively, of income from all farm commodities in those states from 1983 to 1987 (USDA, 1985, 1987 and 1988a). Tobacco farming accounted for 3 to 10 percent of the total employment in the seven most important flue-cured tobacco producing counties in Virginia during 1979 (Wharton Applied Research Center and Wharton Econometric Forecasting Associates, 1980b). Tobacco had an even greater impact on the local economics of various counties in North Carolina (Wharton Applied Research Center and Wharton Econometric Forecasting Associates 1980a).

Registration Summary

Aldicarb has state 24c special local need labels for use on flue-cured tobacco in North Carolina and Virginia to control the tobacco aphid (*Myzus nicotianae* Blackman), root-knot nematodes (*Meloidogyne* spp.), tobacco cyst nematode (*Globodera Ptabacum solanacearum*) [Miller and Gray]) stone lesion nematodes, (*Praytylenchus* spp.), and for suppression of flea beetles (primarily the tobacco flea beetle, *Epitrix hirtipennis* [Melsheimer]) (Rhone Poulenc, c, d, e). In 1978, aldicarb was granted a state 24c special local needs label for use on flue-cured tobacco in North Carolina at the rate of 3 pounds active ingredient (lb ai) per acre to control root-knot nematodes and aphids (Rhone Poulenc, c). In 1982, a second state 24c special local need label for North Carolina was obtained for aldicarb at the 1 to 2 lb ai/acre rate to control aphids and to suppress flea beetles on flue-cured tobacco (Rhone Poulenc, d). That same year a state 24c label was granted for aldicarb in Virginia for the control of nematodes (3 lb ai/acre), aphids (1 to 2 lb ai/acre) and to suppress flea beetle populations (1 to 2 lb ai/acre) on flue-cured tobacco (Rhone Poulenc, e). Granular applicators are used during fertilizer application and hilling (bedding) operation to apply aldicarb within a week before transplanting. For aphid control and flea beetle suppression, granules are applied in a 6- to 12-inch band, and incorporated into or covered with soil to a depth of 2 to 6 inches when forming beds. Tobacco is then transplanted into the treated area (Rhone

Poulenc, d; e). For root-knot nematode control, granules are broadcast at 3 lb ai/acre and incorporated 2 to 4 inches in soil. Soil is then pulled from middles to form beds and tobacco is transplanted into the treated area (Rhone Poulenc, c; d; e). Granules can also be applied in a 12 to 24-inch band, incorporated thoroughly during bed preparation and tobacco transplanted into the treated area. This later treatment also controls aphids.

Acephate is labeled for tobacco as a foliar spray at 0.5 lb ai/acre for control of tobacco aphids, tobacco flea beetles, hornworms, cutworms and grasshoppers and 0.75 lb ai/acre for control of tobacco budworms and cabbage loopers (Valent USA Corporation). Acephate is also labeled for application in the transplant water at 0.75 lb ai/acre for control of flea beetles and cutworms and to aid in the control of aphids (Valent USA Corporation). Acephate, methomyl, carbaryl and methidathion provide flea beetle control for about 1 week after application. However, they do not control flea beetle larvae feeding on tobacco roots.

Endosulfan is registered for control of tobacco aphids, budworms and hornworms (FMC Corporation c). Application rates range from 0.25 to 1.0 lb ai/acre. Endocide Plus is a combination of endosulfan and ethyl parathion that is currently being marketed as a foliar treatment for aphid control on tobacco in Georgia, South Carolina and North Carolina (Southern, 1988). It is a combination of 1 lb ai of endosulfan and 2 lb ai of ethyl parathion/gal and is applied at 1 to 2 qt/acre. Methomyl is registered for aphid control on tobacco at a rate of 0.45 lb ai/acre (E.I. DuPont de Nemours and Company, a). It also controls hornworms, budworms, cabbage loopers and flea beetles. Several other foliar insecticides are currently registered for aphid control on tobacco. These insecticides are no longer effective or have only limited availability and are not viable alternatives to aldicarb.

Disulfoton is labeled at 2.0 to 4.0 lb ai/acre as band or broadcast soil treatments before transplanting to provide systemic control of aphids and flea beetles on tobacco (Mobay Incorporated, a and b). Disulfoton and oxamyl applied as pre-transplant soil treatments are labeled for flea beetle control on tobacco (Mobay, a and b;, E.I. DuPont de Nemours and Company, b).

Carbofuran applied at 4 to 6 lb ai/acre to the soil before transplanting provides excellent flea beetle control on tobacco from 4 to 6 weeks after transplanting (FMC Corporation, a and b). However, carbofuran granules are also under special review by EPA and, therefore, may not be a viable alternative to aldicarb for flea beetle control in the future (U.S. EPA, 1989). Carbofuran is labeled for control of root-knot nematodes at the rate of 6 lb ai/acre (FMC Corporation, a and b). Two formulations, a 15 percent granular and a 4 lb/gal flowable, are available. Carbofuran also controls flea beetles and hornworms feeding on tobacco foliage and wireworms in the soil.

Chlorpyrifos is labeled for control of flea beetle larvae, wireworms, cutworms, and nematodes (Dow Chemical Company). Chlorpyrifos is labeled on tobacco at 5 lb ai/acre for control of root-knot nematodes (Dow Chemical Company). It also controls cutworms, wireworms and flea beetle larvae on tobacco.

Ethoprop at rates of 6 to 12 lb ai/acre, either with or without disulfotan, are registered for control of root-knot nematodes on tobacco (Rhone Poulenc Ag Company, a and b). These materials are also labeled for other nematodes and wireworms, and the combination of ethoprop plus disulfoton is labeled for aphids.

Fenamiphos is labeled on tobacco for root-knot and tobacco cyst nematode control at 4 to 6 lb ai/acre (Mobay Corporation, c). Oxamyl is EPA registered on tobacco for control of root-knot nematodes at 2 lb ai/acre (E.I. DuPont de Nemours and Company, b).

Several fumigant nematicides are alternatives to aldicarb for nematode control (Johnson, 1988c; Melton et al., 1988). They include 1,3-dichloropropene plus chloropicrin, 1,3-dichloropropene, methyl isothiocyanate plus 1,3-dichloropropene plus and chloropicrin.

Pest Infestation and Damage

Aphids: Aphid infestations reach economic levels in all tobacco producing areas of the United States. However, they cause the most severe problems on flue-cured tobacco in Virginia and North Carolina. The tobacco aphid is one of the most important pests of tobacco in Virginia and North Carolina. Prior to its description as a separate species, the tobacco aphid was called the green peach aphid, *Myzus persicae* (Sulzer) (Blackman, 1987). The aphid was first identified as a pest of U.S tobacco in 1946 (Chamberlin, 1958; Dominick, 1949). The tobacco aphid was a serious pest of shade-grown tobacco during the 1950s and 1960s (Guthrie et al., 1956; Tappan, 1963). It was not a major flue-cured tobacco pest again until the mid-1970s, when it caused serious injury to tobacco in North Carolina, Virginia, and Ontario, Canada, (Cheng and Court, 1977; Mistric and Clark, 1979; Semtner, 1977). Very high populations of aphids occurred on Virginia tobacco in 1979, 1981, and 1986-88 (Semtner, unpublished data). Recommended treatment thresholds in North Carolina are reached when 10 percent of the plants sampled in a field are infested with up to 50 aphids per leaf before topping and 20 percent of the plants are infested with aphids at or after topping (Southern, 1988). In Virginia, treatment is recommended when 20 percent of the plants are infested with 50 aphids per leaf (Semtner, 1988c).

The tobacco aphid can cause severe reductions in tobacco yield (Cheng and Hanlon, 1985; Guthrie et al., 1956; Tappan, 1963) and quality (Chamberlin, 1958; Cheng and Court, 1977; Cheng and Hanlon, 1985; Dominick, 1949; Mistrick and Clark, 1979). North Carolina tobacco producers lost $15.0 million due to aphid damage in 1988 (Lampert, personal communication). Semtner (1977) has observed 20 percent reductions in yield and 25 percent reductions in economic returns when populations of aphids are high on flue-cured tobacco. In five tests conducted in 1986-88, 12 percent higher returns were obtained when tobacco was treated with foliar applications of acephate for aphid control than from untreated tobacco (Semtner, unpublished data). Mistric and Clark (1979) comparing aphid-infested and noninfested tobacco reported 50, 3 and 0 percent reductions in the value of flue-cured tobacco leaves picked from the lower, middle and upper stalk leaves, respectively. Tobacco yield is also reduced because aphid-infested leaves are thinner and sometimes smaller. Aphids also vector several non-persistent viral pathogens of tobacco, including potato virus Y, cucumber mosaic, tobacco vein mottling virus, peanut stunt virus, and alfalfa mosaic virus (Lucas, 1975).

Before 1986, the tobacco aphid was generally green or yellow-green in color. In 1985, a red morph of the tobacco aphid first occurred on tobacco in the United States, and by 1987 it had replaced the previously common green morph as the predominant aphid on tobacco. Blackman (1987) found that red morphs of the tobacco aphid in Virginia and North Carolina had a chromosome translocation involving autosome 1 and 3, a characteristic of insecticide resistance in the closely related green peach aphid, *M. persicae*. The red morph of the tobacco aphid appears to be more difficult to control now than the green morph was from 1978 to 1984 (Koziol

and Semtner, 1984; Lampert, personal communication; McPherson and Taylor, 1988; Semtner, 1980, 1983a and 1988a; Semtner and Reed, 1987b and 1989; Southern, 1987, 1988 and 1989).

Flea Beetle: The tobacco flea beetle is an important pest of tobacco in Southeast. Flea beetles occur on tobacco in North Carolina and Virginia throughout the growing season. They can cause serious damage during the first 3 weeks after transplanting. This results in delayed growth and irregular stands of tobacco. Semtner (1984a) has demonstrated that infestations of individual plants (5 to 20 beetles/plant) during the first 2 to 3 weeks after transplanting can reduce cured leaf yields by 18 to 38 percent. Much of this yield reduction is probably caused by the flea beetle larvae, which feed on the root systems of tobacco plants (Martin and Herzog, 1987); for this reason, control during the first 3 weeks after transplanting is critical. Very high flea beetle populations after topping can result in light to moderate damage (Allen, 1940). Late-season infestations generally have little effect on yield, but cause numerous small holes in the leaves (Allen, 1940). The currently recommended treatment thresholds for the tobacco flea beetle are 4 beetles/plant on tobacco up to 3 weeks after transplanting and 60 beetles/plant (40 beetles/plant in Virginia) on tobacco during and after topping (Semtner, 1988c; Southern, 1989).

Nematodes: Root-knot nematodes are important pests of flue-cured tobacco throughout the Southeast. Four species of root-knot nematodes are found on tobacco in this region: *Meloidogyne incognita* (Kofoid & White), *M. hapla* Chitwood, *M. arenaria* (Neal) Chitwood, and *M. javanica* (Treub) Chitwood (Lucas, 1975). *M. incognita* is the most important species of root-knot nematode in North Carolina and Virginia (Barker and Powell, 1988; Barker et al., 1981; Johnson, 1988c; Melton et al., 1988), while *M. javanica* is the predominant nematode pest of tobacco in Florida (Rich and Schenk, 1979). There are many flue-cured tobacco cultivars with resistance to races 1 and 3, the most common races of *M. incognita* in Virginia and North Carolina (Johnson, 1988c; Melton et al., 1988). Recently there has been an increase in the occurrence of the *M. arenaria* and *M. javanica* in North and South Carolina (Fassuliotis, 1982; Fornum et al., 1984). This is a major cause for concern because *M. arenaria* and *M. javanica* are more aggressive pests than *M. incognita* and tobacco cultivars with resistance to races 1 and 3 of *M. incognita* are susceptible to *M. javanica* and *M. arenaria* (Melton et al., 1988).

Root-knot nematodes reduced tobacco yields by 25 percent and more in 1988, resulting in an estimated loss of $8.6 million to North Carolina producers (Melton et al., 1988). It is recommended that a resistant cultivar be used when root-knot nematodes reach 201 to 1,000 larvae/pt of soil collected in the fall (Johnson 1988c; Melton et al., 1988). Moderate levels (1,001 to 3,000 larvae/pt of soil) requires the use of a resistant cultivar and a moderate-to-highly effective nematicide. Populations of over 3,000 root knot larvae/pt should be controlled with a highly effective nematicide in addition to a resistant cultivar. If root-knot resistant cultivars have been injured by root-knot nematodes in a field in the past, the root knot nematode is probably *M. javanica*, *M. arenaria* or a resistant race of *M. incognita* (Melton et al., 1988). The presence of root-knot nematodes and root diseases such as black shank, bacterial wilt or black root rot can cause even greater problems in tobacco fields (Lucas, 1975). Root-knot nematode injury to tobacco predisposes roots to invasion by several root pathogens and results in more severe damage than would occur if the nematodes or pathogens had occurred separately (Lucas, 1975).

The tobacco cyst nematode caused approximately $700,000 damage to flue-cured tobacco in a 10-county area of south-central Virginia in 1982 (Komm et al., 1983). This resulted in an estimated 15 percent loss in income on 837 acres of infested land.

Pest Management

Current Chemical Usage

An estimated 7 percent of the flue-cured tobacco acreage in North Carolina and Virginia was treated with aldicarb annually from 1984 to 1988 (Table 78). Aldicarb was applied annually to an average of 18,804 acres and amounts totalled 40,161 lb ai per year. Of the flue-cured tobacco acreage in North Carolina treated with aldicarb (6 percent), about one-half was for root-knot nematodes and one-half for aphids. In Virginia, approximately 15 percent of total acreage was treated with aldicarb; of this acreage, 80 percent or more was treated for control of aphids and less than 20 percent was treated for nematode control. Johnson (unpublished data) estimated that 16 percent of the flue-cured Virginia tobacco acreage was treated with aldicarb based on a survey of producers. Usage may have increased slightly since that survey was conducted (Campbell, 1982 and 1988). The increased use of aldicarb on tobacco 1986-88 was due to the greater availability of aldicarb and the difficulty of controlling tobacco aphid with alternative insecticides. Table 79 lists the chemical alternatives to aldicarb for aphid, nematode and flea beetle control on flue-cured tobacco.

Most producers use fenamiphos or ethoprop as an alternative to aldicarb for nematode control. Acephate is the primary replacement for aldicarb for control of the tobacco aphid. There is a potential problem with aphid resistance to acephate. Endosulfan, endosulfan plus parathion, and methomyl would also be used for aphid control. The withdrawal of aldicarb from use on flue-cured tobacco would result in an estimated loss of about $3.8 million to producers in North Carolina and Virginia. In addition, the future impact of its withdrawal from the market may leave producers without an effective insecticide for the control of the tobacco aphid. The loss of aldicarb would probably have little effect on the flue-cured tobacco market unless alternative aphicides are not effective against the tobacco aphid. If the tobacco aphid cannot be controlled with the future alternatives, there will be at least a 5 percent reduction in yield and a 5 percent reduction in quality.

Non-chemical Management Alternatives

There are many cultural practices and natural enemies that reduce the need for pesticides on tobacco. However, at this time none of the cultural or natural controls can replace pesticides for the management of aphids, flea beetles and nematodes on tobacco.

Insects: Cultural practices that often help reduce aphid populations on tobacco include: 1) reduction of alternate hosts around tobacco fields and plant beds; 2) early or late transplanting (Semtner, 1984b); 3) early topping (Semtner, unpublished data); 4) proper application of nitrogen fertilizer, and 5) effective sucker control. The reduction of hosts for overwintering aphid populations near tobacco plant beds and tobacco fields may be helpful in reducing infestation pressure in the spring. However, many of the field infestations may be initiated by winged tobacco aphids migrating north from earlier infestations on tobacco and other hosts south and west of North Carolina and Virginia. Proper timing of transplanting (Semtner, 1984c), and stalk cutting and root destruction, after the completion of harvest (Kinard et al., 1972) help to reduce the impact of flea beetles on tobacco.

Many natural factors help to reduce aphid populations on tobacco. These factors include beneficial organisms, high temperatures and heavy, beating rains. Beneficial insects that help to regulate aphid populations on tobacco include the convergent lady beetle (*Hippodamia*

convergens), syrphid fly larvae [*Allograpta obliqua* (Say) and others], green lacewings (*Chrysopa* spp.), and probably the stilt bug *Jalysus wickhamii* (Hamid, 1987). Several entomophagus pathogens are often responsible for epizootics, which rapidly reduce aphid populations late in the season. These factors are helpful in regulating aphid populations on tobacco but under many circumstances do not keep populations below the economic threshold levels (Hamid, 1987).

Nematodes: The most important practices for the nonchemical control of nematodes are the use of resistant cultivars and crop rotation. Root-knot nematode resistance is present in several flue-cured tobacco cultivars including 'Coker 176', 'Coker 347', 'K 326', 'K 399', 'McNair 373', 'NC 37NF', 'NC 95', 'NC 567', 'Speight G-28', and 'Speight G-70' (Melton et al., 1988). The use of resistant cultivars in combination with a nematicide and crop rotation make the root- knot nematode relatively easy to manage unless the infestation is a resistant race or species (*M. javanica*, *M. arenaria*). Crop rotation is very important in reducing nematode populations from one year to the next. The Reduce Nine Pests (R-9-9) program in North Carolina encourages cultural practices to help reduce overwintering populations of the tobacco root-knot nematode (Melton et al., 1988). This program includes cutting stalks immediately after harvest and disking out the stubble. Approximately 2 weeks later the field is disked again and seeded into a cover crop. The tobacco cyst nematode can also be managed effectively using resistant cultivars, crop rotation and an effective nematicide (Elliott et al., 1986; Johnson et al., 1989).

Impact on Beneficial Insects

Aldicarb does not have a serious, direct impact on most beneficial insects such as the *Heliothis* parasitoids, [*Campoletis sonorensis* (Cameron)], the red-tailed wasp, *Cardiochiles nigriceps* (Vier.)], the hornworm parasitoid, *Cotesia congregata* (Say), and the convergent lady beetle, *Hippodamia convergens*. However, *Jalysus wickhamii* VanDuzee, a predator of hornworm and budworm eggs, is seriously affected by aldicarb because it also feeds on plant sap in addition to feeding on eggs (Semtner, 1979).

Comparative Performance Evaluation

Table 79 compares the efficacy ratings for aldicarb and various alternative insecticides and insecticide/nematicides for the control of aphids, flea beetles and root-knot nematodes on flue-cured tobacco. No other insecticide applied before transplanting was as effective as aldicarb against the tobacco aphid. Before 1979, disulfoton provided good-to-excellent aphid control on tobacco (Semtner, 1983b); however, since then it has given only poor to good control (Jones et al., 1985; Semtner, 1983b, 1983c and 1987b; Semtner and Reed, 1987a and 1989). The 15G formulation of disulfoton is more effective than the 8EC formulation (Semtner, 1983b). Acephate applied in the transplant water often suppresses aphid populations on tobacco for the first 3 to 6 weeks after transplanting. The acephate transplant water treatment is often equal to or more effective than disulfoton, but it is usually less effective and less consistent than aldicarb (Semtner, 1982, 1983c and 1987a; Semtner and Reed, 1989). Acephate applied in this manner also provides control of cutworms and flea beetles. Fenamiphos is not labeled for control of the tobacco aphid. However, recent research shows that it is usually more effective against the tobacco aphid than disulfoton or the acephate transplant water treatment, but less effective than aldicarb (Semtner and Reed, 1987a). The rate of fenamiphos (6.0 lb ai/acre) that provides good control of aphids is much more expensive than the rate of aldicarb that gives similar control.

The foliar insecticides, acephate, endosulfan, and endosulfan plus methyl parathion remain viable alternatives to aldicarb for aphid control on tobacco (Table 79). In addition, methomyl gives fair to good aphid control, but its residual control is shorter than that obtained with endosulfan and acephate (Semtner 1988a and 1988b). There have been reports of poor aphid control with both acephate and endosulfan. Koziol and Semtner (1984) reported some tolerance to acephate from one location in Virginia during 1981. Lampert (personal communication) reported that the acephate LD_{50} for aphids collected in 1987 and 1988 was five times higher than that for a colony of aphids collected from tobacco in 1983. However, the rates of acephate applied continue to provide good aphid control under most field conditions. Semtner et al. (1989b) reported poor aphid control on tobacco after topping in a test conducted in 1988. Endosulfan has given good-to-excellent control of aphids on tobacco in recent years (Semtner, 1989a and 1989b; Southern, 1988 and 1989). However, Thurston (1965) reported some aphid control failures with endosulfan during the early 1960s. Endosulfan leaves high residues on tobacco (McPherson, unpublished data). To avoid this problem, it is recommended that endosulfan be applied only before topping (Southern, 1988). Tobacco fields treated with acephate can be re-entered as soon as the spray deposit has dried, while endosulfan and endosulfan plus methyl parathion have 24- and 48-hour re-entry times, respectively. Endosulfan plus methyl parathion has given fair to good control of the tobacco aphid in North Carolina tests (Southern, 1988).. Other insecticides that are still labeled for aphid control on tobacco have not been effective [malathion (Southern, 1989), methyl parathion (McPherson and Taylor, 1988; Semtner, 1988a; Southern, 1989] or may be withdrawn from the market. Monocrotophos will be withdrawn from the market effective 30 June 1989 and cannot be used after 30 September 1989 (Tinsworth, 1988).

Almost all foliar treatments for aphid and flea beetle control are applied with high-clearance boom sprayers (self- propelled or tractor-mounted). These sprayers are usually fitted with rotary-type pumps operated at 40 to 100 psi and deliver 10 to 50 gal/acre (Semtner, 1986; Southern, 1988). Booms are usually fitted with three nozzles per row, one centered over the bud, and a matching pair oriented inward at a 45 degree angle on each side of the plant. The side nozzles direct the spray down to the lower leaves on each side of the row. Hollow-cone nozzles are used most frequently, but solid-cone and flat fan tips are also used. Less than 1 percent of the crop is treated with aerial applications.

Table 80 compares the returns ($/acre) for aldicarb and its alternatives for aphid and flea beetle control on flue-cured tobacco in various experiments at the Virginia Polytechnic Institute & State University, Southern Piedmont Agricultural Experiment Station (Blackstone, Virginia) and for various farm test demonstrations conducted throughout south-central Virginia from 1977-88. Aldicarb (1 to 1.5 lb ai/acre) increased returns over the untreated check by $400 per acre in 43 tests. In 23 tests comparing acephate transplant water treatment and aldicarb to an untreated check, the aldicarb increased returns by $137 per acre over the acephate transplant water treatment and $334 per acre over the untreated check. There was no difference in returns between aldicarb and the ethoprop plus disulfoton treatment in seven tests. Aldicarb increased yield by $96 per acre over treatment with carbofuran. Aldicarb at 3 lb ai/acre increased returns over a rate of 1 to 1.5 lb ai/acre by $211 per acre. The application of acephate as a foliar treatment (1 to 4 applications/year) for aphid control increased returns by $198 per acre over the untreated check.

Aldicarb aids in the control of the tobacco flea beetle, but it is not the preferred chemical for the control of this pest. Table 79 compares aldicarb to several of its alternatives for the control of tobacco flea beetles. Carbofuran is the most effective treatment, but acephate and oxamyl transplant water treatments provide excellent flea beetle control for the critical period during the

first 2 to 3 weeks after transplanting (Semtner, 1982, 1983c and 1987a). Disulfoton and fenamiphos (not labeled) provide flea beetle control similar to aldicarb (Table 79). Acephate applied as a foliar spray provides good control of flea beetles, while methomyl gives fair control. Other foliar treatments labeled for flea beetles include methyl parathion, carbaryl and methidathion.

Fenamiphos is the best alternative to aldicarb for nematode control (Table 79). Compared to aldicarb, fenamiphos gives superior control of the root-knot nematode (Table 79) and is much more effective against the tobacco cyst nematode (Johnson, 1988a, 1988b, 1988c and 1989). Ethoprop provides nematode control similar to aldicarb, but some researchers have reported yields in nematode infested fields treated with ethoprop average about 10 percent lower than those treated with aldicarb (Barker and Powell, 1988; Melton, personal communication). Carbofuran and oxamyl (applied broadcast or in the transplant water) are less effective than aldicarb against nematodes (Table 79). The fumigant nematicides provide excellent control of root-knot nematodes (Johnson, 1988c; Melton et al., 1988), but most require specialized application equipment and have a 21-day waiting period before transplanting.

Barker and Powell (1988) obtained about a 20 percent increase in yield with aldicarb over the untreated check in 35 tests conducted in North Carolina tobacco fields infested with root-knot nematodes. They obtained less than 10 percent increases in yields with ethoprop in the same tests. In 23 tests conducted in North Carolina, Todd (1981) reported 260 lb/acre increases in yield using aldicarb in flue-cured tobacco fields infested with root-knot nematodes, whereas in 125 other tests ethoprop resulted in 287 lb/acre higher yields than the untreated check (Todd, 1981). Use of fenamiphos usually results in slightly higher yields than aldicarb (Melton, response to questionnaire).

Comparative Chemical Costs

Acephate, a foliar insecticide, is the primary alternative to aldicarb for the control of the tobacco aphid (Table 81). Acephate would be used on an estimated 80 to 90 percent of the tobacco acreage currently treated with aldicarb for aphid control in North Carolina and Virginia, respectively, whereas endosulfan would be used on 5 to 10 percent of the acreage currently treated with aldicarb. A combination of endosulfan plus parathion would replace an estimated 10 percent of the aldicarb treated acreage in North Carolina and methomyl would be used on an estimated 5 percent of the acreage treated with aldicarb for aphid control in Virginia. The use of any of these alternatives for aphid control will result in an estimated 5 percent loss in yield. Value due to a decrease in quality will be reduced by 5 percent for each of the alternatives in North Carolina and by 2 percent for acephate and endosulfan and 3 percent for methomyl in Virginia (Table 81).

The primary alternatives to aldicarb for nematode control in North Carolina and Virginia are ethoprop and fenamiphos (Table 81). An estimated 50 and 75 percent of the acreage currently treated with aldicarb for nematode control in Virginia and North Carolina, respectively, would be treated with fenamiphos. Ethoprop will be used for nematode control on 25 and 50 percent of the aldicarb treated acreage in North Carolina and Virginia, respectively. The switch from aldicarb to fenamiphos will result in an estimated 2 percent increase in yield in North Carolina and will have no effect on yield in Virginia (Table 81). The switch to ethoprop on nematode infested tobacco land will result in an estimated 10 percent reduction in yield in North Carolina and a 5 percent reduction in yield in Virginia. The use of ethoprop and fenamiphos instead of aldicarb for nematode control is estimated to have no effect on tobacco quality (Table 81).

Table 82 lists the costs of aldicarb and its alternatives for the control of insects and nematodes on tobacco. Aldicarb applied at 1 to 2 lb ai/acre is relatively expensive when compared to one foliar application of acephate. Endosulfan is generally more expensive than acephate and two applications of the high rate is similar to one application of 1.0 lb ai/acre of aldicarb. Disulfoton is slightly less expensive than aldicarb, but it is also less efficacious. Except for oxamyl and chlorpyrifos most soil nematicide/insecticides are more expensive to apply for nematode control than aldicarb (Table 82).

The cost of aldicarb application was not included in the analysis because it is applied during the normal bedding operation, when fertilizer is being applied. However, a separate broadcast application of aldicarb may be rather expensive. The liquid formulations of fenamiphos, ethoprop and disulfoton would also not increase application costs because they are usually applied with herbicides and fungicides which are also applied as broadcast treatments.

Under field conditions there have been many reports of increased yield in the absence of significant insect or nematode pressure following the use of aldicarb on tobacco. Barker and Powell (1988) demonstrated that aldicarb (1.3 to 4.0 lb ai/acre) enhances tobacco growth and yield in the absence of major pests. Response to aldicarb was influenced by cultivar, soil type and irrigation. The results presented in Table 80 also indicate that aldicarb enhances the yield of flue-cured tobacco.

Economic Impacts

Questionnaires were completed by extension entomologists and plant pathologists working on flue-cured tobacco in Virginia and North Carolina. They were asked how much aldicarb was used in their state for the control of specific pests and what alternatives were available for the control of each pest. The cost of each major alternative was given along with the cost associated with their application. The percent of the total acres treated with aldicarb in each state was divided according to the target pest. The estimated use rates for aldicarb were 1.5 lb ai/acre for aphid control and 3.0 lb ai/acre for nematodes. The number of acres treated for each pest was multiplied by the corresponding estimated application rate to determine the number of pounds active ingredient of aldicarb used for a specific purpose. Using this procedure, the total acres treated and the number of lb/ai of aldicarb used each year were estimated (Table 77).

The loss in yield and quality associated with the withdrawal of aldicarb from the market was calculated using the 5 year average (1984-88) for yield and price of flue-cured tobacco in each state. This is probably a conservative estimate of the impact of aldicarb on tobacco production, since the use of aldicarb would probably result in higher yields and values than the state averages. National prices (Mason, 1989) for aldicarb and its alternatives were adjusted to reflect local market conditions. The application costs were based on estimates for North Carolina (Melton, response to survey; Southern, response to survey) and Virginia (Coppedge, personal communication). The cost of application of the aldicarb and the other preplant treatments were not included because these treatments are usually applied during an operation that is carried out whether or not the pesticides were applied. The survey responses were also used to determine the percentage of the aldicarb-treated acreage that would be treated with each of the alternatives. Estimates were also made to determine the losses in yield and value associated with switching from aldicarb to one of its alternatives. Losses were calculated on a $/acre basis and included changes in pesticide costs,

application costs, yield and value of the cured product. The losses associated with switching to each alternative were calculated by state, pest and alternative.

Table 81 shows the estimated effects of the alternatives to aldicarb on the yield and value of tobacco when compared to the aldicarb treatment. Switching from aldicarb to fenamiphos will result in a 2.5 percent increase in yield in North Carolina, but will have no effect on yield in Virginia (Table 81). The use of ethoprop instead of aldicarb on nematode-infested tobacco land will result in a 10 percent reduction in yield in North Carolina and a 5 percent reduction in yield in Virginia. The use of foliar insecticides instead of aldicarb for aphid control will cause a 5 percent reduction in yield in both Virginia and North Carolina. The switch to foliar insecticides will also cause reductions in value of 5 percent in North Carolina and 2 to 3 percent in Virginia (Table 81).

The cost of using fenamiphos and ethoprop for nematode control on flue-cured tobacco was higher than the cost of using aldicarb (Table 83). One foliar application of acephate, endosulfan, or endosulfan plus parathion in North Carolina averaged about $16.25/acre less than a pretransplant band application of aldicarb at 1.5 lb ai/acre. In Virginia, one application of the alternative foliar insecticides costs from $12.00 to $13.00/acre less than treatment with the 10 lb/acre aldicarb at 1.5 lb ai/acre (Table 83). The use of fenamiphos instead of aldicarb would result in a 54 lb/acre increase in yield in North Carolina and no change in yield in Virginia (Table 81). The replacement of aldicarb with ethoprop would cause an estimated 216 lb/acre reduction in yield in North Carolina and a 101 lb/acre reduction in yield in Virginia. The use of foliar insecticides instead of aldicarb for aphid control would reduce yield in both states by 107 to 108 lb/acre (Table 81).

The costs of foliar insecticides were similar for both states (Table 83). The costs of methomyl and endosulfan were estimated to be about $0.50 to $1.50/treated-acre higher, respectively, in Virginia than in North Carolina (Table 83). Application costs for foliar insecticides were $2.50/acre in North Carolina (Southern, response to survey) and $5.75/acre in Virginia (Coppedge, personal communications) (Table 83).

The estimated impact of the withdrawal of the aldicarb registration for tobacco is a loss of $3.8 million (Table 84). Reduced aphid control and the loss of yield enhancement associated with aphid control would cause a loss of $3.2 million, while reduced nematode control would result in an estimated loss of $552,600. The total loss in production ranged from $379/acre when ethoprop was used instead of aldicarb in a field infested with root-knot nematode, to an increase of $42/acre in a field treated with fenamiphos. The use of foliar insecticides instead of aldicarb will result in an estimated loss of $231 to $334/acre. This loss associated with the withdrawal of aldicarb from the market could be even greater in the future if the tobacco aphid remains a persistent problem and if aldicarb continues to provide good control.

Limitations of the Analysis

The exact amount of aldicarb used on flue-cured tobacco in Virginia and North Carolina was not available. However, sales figures for aldicarb were available by county in each state. Aldicarb is known to improve tobacco yield, but the amount related to growth enhancement and that associated with pest control are not easy to separate. The number of applications of alternative foliar insecticides for aphid control were not available, so they were estimated.

Table 77. Flue-cured tobacco production in North Carolina and Virginia, 1984-88

State	Area planted		Yield		Crop value	
	year	acres	thousand lb	(lb/acre)	thousand $	($/lb)
North Carolina	1984	262,000	568,609	2,170	1,027,738	1.81
	1985	241,900	537,226	2,220	921,038	1.71
	1986	206,600	429,590	2,080	665,415	1.53
	1987	217,000	452,490	2,085	715,325	1.58
	1988	242,000	537,670	2,220	866,800	1.61
	AVERAGE	233,900	505,117	2,160	839,263	1.66
Virginia	1984	38,000	86,640	2,280	157,760	1,82
	1985	30,000	65,100	2,170	114,900	1.76
	1986	28,000	57,540	2,055	87,060	1.51
	1987	28,000	58,380	2,085	89,610	1.53
	1988	35,000	71,800	2,050	114.880	1.60
	AVERAGE	31,800	67,892	2,135	112,842	1.66

Sources: USDA, 1985, 1987, 1988a and 1989.

Table 78. Use of aldicarb insecticide/nematicide on flue-cured tobacco in North Carolina and Virginia, 1984-88

State	Planted acres	% of acres treated	Treatment ai/acre	Acres treated	Chemical applied (lb ai/year)
North Carolina	233,900	3 n[2] 3 i[2]	3.0 1.5	7,017 7,017	21,050 10,525
State total		6	2.25	14,034	31,575
Virginia	31,800	3 n[2] 12 i[2]	3.0 1.5	954 3,816	2,862 5,724
State total		15	1.8	4,770	8,586
Grand total	265,700	7.1	2.14	18,804	40,161

[1]Source: Survey of state extension specialists in December 1988.
[2]n = nematicide, i = insecticide

Table 79. Comparison of aldicarb and alternative foliar and soil applied chemicals for control insect and nematode pest of tobacco in North Carolina and Virginia

Pest controlled	Chemical	Application[1] method	Rate (lb ai/acre)	Control[2] rating
Tobacco aphid	Aldicarb	PPI	1.0-2.0	G-E
	Aldicarb	PPI	3.0	E
	Acephate	Foliar	0.5-0.75	G-VG
	Acephate	TPM	0.75	F-G
	Disulfoton 15G	PPI	2.0-4.0	P-G
	Disulfoton 8EC	PPI	2.0-4.0	P-F
	Endosulfan	Foliar	0.5-1.0	G-VG
	Endosulfan + methyl parathion	Foliar	0.25+0.5 to 0.5+1.0	G
	Ethoprop + disulfoton	PPI	6.0+3.0 to 8.0 + 4.0	P-G
	Fenamiphos	PPI	6.0	P-G(NL)
	Methomyl	Foliar	0.45	F-G
Tobacco flea beetle	&Aldicarb	PPI	1.0-2.0	F
	Acephate	Foliar	0.5-0.75	G
	Acephate	TPW	0.75	G-E
	Carbofuran	PPI	4.0-6.0	G-E
	Disulfoton	PPI	2.0-4.0	F
	Methomyl	Foliar	0.225-0.45	F
	Methyl parathion	Foliar	0.5-1.0	F
	Oxamyl	TPW	0.25	G
	Oxamyl	PPI	2.0	F
Root-knot nematodes	Aldicarb	PPI	3.0	G
	Carbofuran	PPI	6.0	F
	Chlorpyrifos	PPI	3.0-5.0	F
	1,3-dichloropropene	Injected	6.0 to 18.0 gal	E
	Ethoprop	PPI	6.0-8.0	F-G
	Ethoprop + Disulfoton	PPI	6.0+3.0 - 8.0+4.0	F-G
	Fenamphos	PPI	4.0-6.0	E
	Oxamyl	PPI	2.0	F
	Oxamyl	TPW	0.25	P-F

[1]PPI = soil incorporated before transplanting; TPW = applied in the transplant water; Soil inj. = soil injected at least 21 days before transplanting.
[2]Control rating: P=poor; F=fair; G=good; VG=very good; E=excellent; NL=not labeled.
Insecticide ratings: Modified from Southern (1988) and Semtner (1988c).
Nematode ratings modified from Melton et al. (1988) and Johnson (1988c)

Table 80. Comparison of returns for flue-cured tobacco treated with aldicarb and various alternative insecticide/nematicides for aphid control in Virginia, 1977-88

Product	Rate (lb ai)	Method	Chemical cost ($/acre)	Return ($/acres)	Difference vs check	
					$ Increase	% Increase
Aldicarb	1 to 1.5	PPI	43	4,162	400	11
Untreated check		--		3,762		
Aldicarb	1 to 1.5	Band PPI	23	4,318	334	8
Acephate	0.75	Transplant water		4,181	197	5
Untreated check		--		3,984		
Aldicarb	1 to 1.5	Band PPI	7	4,270	954	29
Ethoprop + disulfoton	[?]	Broadcast PPI		4,267	95	29
Untreated check		--		3,316		
Aldicarb	1 to 1.5	Band PPI	11	4,529	1100	32
Carbofuran	4	Broadcast PPI		4,433	1004	29
Untreated check		--		3,429		
Aldicarb	1 to 1.5	Band PPI	7	3,977	719	22
Aldicarb	2	Band PPI		4,188	930	29
Untreated check		--		3,258		
Aldicarb	1 to 1.5	Band PPI	6	4,452	666	18
Fenamiphos	6	Broadcast PPI		4,464	678	18
Untreated check		--		3,786		
Acephate	0.75	Foliar spray	19	4,057	198	5
Untreated check		--		3,859		

[1]Based on average nominal market prices during the year of the test. Sources: Semtner 1983b, 1983c, 1987a, 1987b, 1988b, unpublished data, Semtner and Reed 1987a, Semtner et al. 1989a.

Table 81. Chemical alternatives to use of aldicarb on flue-cured tobacco and their influence on yield and value

Target pest	State	Product	% Acres treated	Change in yield		Change in value
				%	lb/acre	
Root-knot nematode	North Carolina[1]	Fenamiphos	75	+2.5	+54	0
		Ethoprop	25	-10.0	-216	0
	Virginia[2]	Fenamiphos	50	0.0	0	0
		Ethoprop	50	-5.0	-101	0
Tobacco aphid	North Carolina[3]	Acephate 80	-5.0	-108	-5	-0.08
		Endosulfan	10	-5.0	-108	-5
		Endosulfan + parathion	10	-5.0	-108	-5
	Virginia[4]	Acephate 90	-5.0	-107	-2	-0.03
		Endosulfan	5	-5.0	-107	-2
		Methomyl 5	-5.0	-107	-3	-0.05

1/Source: T. A. Melton, North Carolina State University.
2/Source: C. S. Johnson, Virginia Polytechnic Institute and State University.
4/Source: P. J. Semtner, Virginia Polytechnic Institute and State University.
3/Source: P. S. Southern, North Carolina State University.
5/Change in yield = average yield by state (Table 78) x percent change in yield (0.01).
6/Change in value = average value ($/lb) by state (Table 78) x percent change in value (0.01).

Table 82. Application rates and prices for aldicarb and its alternatives for use on flue-cured tobacco in North Carolina and Virginia, 1988

Application method	Insecticide	Cost of material[1]		$/lb ai
		(lb ai/acre)	($/acre)	
Foliar	Acephate	0.5-0.75	5.00-7.50	10.00
	Endosulfan	0.5-1.0	4.25-8.50[2]	8.50
	Endosulfan + ethyl parathion	0.25+0.5 to 0.5+1.0	8.00-16.00	16.00[3]
	Methomyl	0.45	8.00	17.78
Soil before transplanting	Aldicarb-Insecticide rate	1.0-2.0	17.50-35.00	17.50
	Aldicarb-Nematicide rate	3.0	52.50	17.50
	Carbofuran	4.0-6.0	44.00-66.00	11.00
	Chlorpyrifos	2.0-5.0	17.00-42.50	8.50
	Disulfoton 15G	2.0-4.0	13.33-26.67	6.67
	Disulfoton 8EC	2.0-4.0	9.50-19.00	4.75
	Ethoprop	6.0-8.0	54.00-72.00	9.00
	Ethoprop + Disulfoton	6.0+3.0 to 8.0+4.0	70.00-94.00	11.67[4]
	Fenamiphos	6.0	100.00	16.67
	Oxamyl	2.0	40.	20.00
Transplant water	Acephate	0.75	7.50	10.00
	Oxamyl	0.25	5.00	20.00
	1,3, dichloropropene	6.0 to 18.0 gal	54.00-162.00	9.005

[1]Sources: Ben Mason (AGCHEMPRICE, El Paso, Texas). Prices were adjusted to reflect regional cultivars based on survey of state extension specialist in December 1988.
[2]Southern States Cooperative, Inc., Richmond, Virginia, (2EC formulation).
[3]0.5 lb ai endosulfan + 1.0 lb ai ethyl parathion.
[4]1.0 lb ai ethoprop + 0.5 lb ai disulfoton.

Table 83. Pesticide and application costs for flue-cured tobacco treated with aldicarb and its alternatives, 1984-88

State	Target pest	Alternative chemical	Pesticide[1] + Application[2] costs ($/acre)	Total[3] costs ($/acre)	Difference[4] in costs ($/acre)
North Carolina	Root-knot nematode	Aldicarb	52.50 + –	52.50	-
		Fenamiphos	100.00 + –	100.00	+47.50
		Ethoprop	72.00 + –	72.00	+19.50
Virginia	Root-knot nematode	Aldicarb	52.50 + –	52.50	-
		Fenamiphos	100.00 + –	100.00	+47.50
		Ethoprop	54.00 + –	54.00	+1.50
North Carolina	Tobacco aphid	Aldicarb	26.25 + –	26.25	-
		Acephate	7.50 + 2.50	10.00	-16.25
		Endosulfan	7.50 + 2.50	10.00	-16.25
		Endosulfan + Parathion	7.50 + 2.50	10.00	-16.25
Virginia	Tobacco aphid	Aldicarb	26.25 + –	26.25	-
		Acephate	7.50 + 5.75	13.25	-13.00
		Endosulfan	8.50 + 5.75	14.25	-12.00
		Methomyl	8.00 + 5.75	13.75	-12.50

1/Cost of 3.0 lb ai/acre rate of aldicarb for control of root- knot nematodes and 1.5 lbs ai/acre rate for aphids and the suggested rates for alternatives.
2/Sources: E. Y. Coppedge, Virginia Cooperative Extension Service, P. S. Southern, North Carolina State University.
3/Total costs = pesticide costs + application costs.
4/Difference in cost = cost of alternative - the cost of using aldicarb (3.0 lb ai/acre for nematodes and 1.5 lbs ai/acre for insect control).

Table 84. Influence of aldicarb and its alternatives on the predicted value of flue-cured tobacco in North Carolina and Virginia, 1984-88

State	Target pest	Alternative chemical	Treated acres[1]	Predicted value[2] ($/acre)	Change in ($) value[3]	Change $ per acres in net returns [4]	Total change net returns [5] (x 1000)
North Carolina	Root-knot nematode	Aldicarb	7,017	3,586	--	--	--
		Fenamiphos	5,263	3,675	+90	+42	+221.0
		Ethoprop (8lbs Al)	1,754	3,227	-359	-379	-664.8
Virginia	Root-knot nematode	Aldicarb	954	3,544	--	--	--
		Fenamiphos	477	3,544	0	-48	-22.9
		Ethoprop (6 lbs/Al/acre)	477	3,366	-178	-180	-85.9
North Carolina	Tobacco aphid	Aldicarb	7,017	3,586	--	--	--
		Acephate	5,613	3,236	350	-334	-1,874.7
		Endolsulfan	702	3,236	350	-334	-234.5
		Endosulfan + Parathion	702	3,236	350	-334	-234.5
Virginia	Tobacco aphid	Aldicarb	3,816	3,544	--	--	--
		Acephate	3,434	3,300	-244	-231	-793
		Endosulfan	191	3,300	-244	-232	-44.3
		Methomyl	191	3,265	-279	-267	-50.9
Total loss							-3,784.5

[1]Based on the percent of acreage expected to be [treated] with the alternative chemical from Table 82.
[2]Value ($/acre) = predicted value of crop if aldicarb or an alternative is used. This includes influence of alternative on yield and price.
[3]Total change in value = difference in predicted value of the tobacco treated with the alternative pesticide and the predicted value of tobacco treated with aldicarb.
[4]Change in returns = change in value [including yield + quality +] pesticide and application costs.
[5]Total change = treated acres x change in returns.

Table 85. Flue-cured tobacco acreage treated with aldicarb and the percent of treated acres meeting proposed use restrictions North Carolina and Virginia, 1984-88

State	Annual average acres planted	% treated with aldicarb	Target pests	% of aldicarb treated acreage meeting use restrictions
North Carolina	23,900	6	3 percent aphids, 3 percent root-knot nematodes	99
Virginia	31,800	15	12 percent aphids, 3 percent root-knot nematodes	99

Sources: Surveys completed by C. S. Johnson, Virginia Polytechnic Institute and State University and T. A. Melton, North Carolina State University (original estimate modified through personal communications).

Aldicarb Use on Sugarcane

Freddie A. Johnson and Wendel F. Matinkovic

Sugarcane (*Saccharum officinarum* L.) is produced primarily for the processing into cane sugar, but it is also used for replanting (seed cane) and for the production of syrup. Sugarcane production data are summarized in Table 86. Florida is the leading sugarcane producing state in total acreage, production, and value. Most (75 percent) of Florida production is in Palm Beach county; the remaining acreage is in Hendry, Glades and Martin counties, which are located in southern Florida near Lake Okeechobee. Hawaii is the second largest U.S. sugarcane producer. Producers in Hawaii harvest on a two-year cycle, called gap planting, which results in a half harvest every two years and a complete harvest every four years. Florida, Louisiana and Texas producers harvest only one-time per year.

Registration Summary

Aldicarb is applied to sugarcane at-planting at the rate of 2.1 to 3.0 pounds active ingredient (lb ai) per 1,000 feet of row. Aldicarb is applied on top of newly planted cane and is covered immediately with 6 inches of soil. Aldicarb is labelled for application to sugarcane <u>only</u> in Louisiana. The only target pests for aldicarb treatment are nematodes.

Pest Infestation and Damage

There are several nematode species that pests of sugarcane (Nickle, 1984). The major nematode pests of sugarcane are described below.

<u>Sugarcane Root-Knot Nematodes:</u> *Meloidogyne* spp. is common and can be a serious pest of sugarcane in sandy and muck soils. However, *M. incognita* and *M. graminicola* are probably the most important species on sugarcane. It is estimated that the soils of 30 percent of worldwide sugarcane fields are infested with root-knot nematodes (Birchfield, 1969; the Society of Nematologists Committee on Crop Losses, 1971). Root-knot nematode disease is the most economically important of all nematode diseases on sugarcane worldwide. Birchfield (1969) reported that yield losses can average 5 tons/acre.

Few commercial cultivars are known to have root-knot resistance. Some cultivars that have been selected for vigor may have moderate resistance. Crop rotation and fallow plowing are not normally practiced in sugarcane culture for weed control, but would perhaps control root-knot nematode if a nonhost crop were to be used in the rotation program. Carbamate nematicides (e.g., carbofuran and aldicarb) are highly effective in controlling root-knot and other plant-parasitic sugarcane nematodes (Nickle, 1984). Organophosphates (e.g., Mocap, Dasanit and Nemacur) are reported to be equally effective in low dosages applied as an in-furrow treatment at planting. Biological control may eventually be realized by use of a protozoan that has an affinity for root-knot larvae; Birchfield and Antonopoulas (1965) found it common in Louisiana sugarcane fields.

<u>Lesion and Meadow Nematodes:</u> Several lesion and meadow nematodes (*Pratylenchus* spp.) are parasitic on sugarcane. The most common are *P. brachyurus* and *P. zeae*. The lesion nematode, *P. inquirenda* was reported in Hawaiian sugarcane as far back as 1888. Numerous workers have reported additional species on Hawaiian sugarcane since that time. Birchfield and Martin (1956) found *P. brachyurus* the most common lesion nematode in Louisiana sugarcane fields. Kahn (1959) found 76 percent of soil samples collected from Louisiana sugarcane fields to be infected with *P. brachyurus* and or *P. zeae*. Yields and sugar losses caused by lesion nematodes have not been estimated. However, Birchfield (1969) found sugarcane tonnage was increased 11 to 18 percent when lesion nematode infested soils in Louisiana were treated with aldicarb, ethoprop or fensulfothion. Infestation by *Pratylencus* spp. is second only to root-knot nematode infestation in economic importance.

There are no sugarcane cultivars with resistance to *Pratylencus* spp. Traditionally sugarcane cultivars are selected for higher sucrose yields, not for nematode resistance. *Pratylenchus* spp. are easily controlled with nematicides. The application of organophosphate and carbamate nematicides at planting time can increase sugarcane yield by 5 tons/acre (Nickle, 1984). Crop rotation is ineffective in controlling *Pratylenchus* spp. due to its wide host range and holdover in weed hosts in the field. No known biological controls are available for controlling this nematode at present.

<u>Lance Nematodes:</u> Several species of lance nematodes (*Hoplolaimus* spp.) infest sugarcane, including *H. columbus*, *H. tylenchiformis*, *H. galeatus* and *H. seinhorsti*. Flor (1930) listed *Hoplolaimus* among factors increasing root-rot disease of sugarcane in Louisiana. Astudillo (1979) reported *H. columbus* damage to sugarcane. Sugarcane infested by *H. columbus* is stubby, sparse and has decayed roots (Astudillo, 1979). The parasite causes necrosis and damage to root parenchyma where the nematode feed in sugarcane roots. Fresh and dry root and shoot weights are reduced by this nematode. Visible top symptoms have not been observed on sugarcane.

The economic importance of lance nematodes on sugarcane is not known. Most nematicide tests involving lance nematodes have been carried out under field conditions where other nematodes such as *Pratylenchus* spp., *Helicotylenchus* spp., *Criconemella* spp. and *Meloidogyne* spp. occur. Lance nematodes are believed to cause economic losses based on greenhouse tests where controlled conditions show that lance nematodes cause weight reduction of tops and roots. With this indirect evidence plus common occurrence of several *Hoplolaimus* spp. in many areas where sugarcane is grown, it is believed to cause extensive production losses (Nickle, 1984).

There are no known cultivars of sugarcane resistant to lance nematodes. Fallow plowing is an effective cultural control, but impractical because of increasing land values. Soybeans and corn should not be used in rotation programs involving sugarcane where large nematode populations are present. These two crops are good hosts and keep lance nematode populations high. Birchfield (1965) found that nematicides control lance nematodes and increase sugarcane production. Johnsongrass is a good host for lance nematodes and sugarcane land should be kept free of this weed to reduce lance nematode populations.

<u>Stunt-Stylet nematodes:</u> Birchfield (1953) was the first to report a species of stunt-stylet nematode (*Tylenchorhynchus martini*) on sugarcane in Louisiana. Host-plant studies showed all Louisiana cultivars of sugarcane were susceptible. Since then *T. martini* has been reported in all

sugarcane-growing areas of the world. Other species that feed on sugarcane are: *T. claytoni, T. acutus, T. nudus, T. dactylurus, T. curvus, T. crassicaudatus, T. brevilineatus* and *T. elegans* (Prasad, 1972).

The economic importance of stunt-stylet nematodes on sugarcane is not great. Sugarcane responds to soil fumigation and granular applications of nematicides where this nematode is present in large numbers. Ethylene dibromide increases sugarcane production 3 tons/acre (15 percent) compared to untreated sugarcane when this nematode is present (Birchfield, 1965). Recent field experiments with newer organophosphate and carbamate nematicide granules applied on plant cane confirmed these results (Nickle, 1984).

Resistant sugarcane cultivars are not available for control of *Tylenchorhynchus* spp. This nematode group has a wide host range and resistant or immune crops of economic importance are unknown for rotation with sugarcane. Nematicides are available that will control this nematode effectively. However, the margin between use of nematicides and making a profit is narrow with this nematode therefore the use of chemicals for control is questionable. Crop rotation is not effective because these nematodes can live long periods without food and they have a wide host range.

Spiral Nematodes: A species of spiral nematode (*Helicotylenchus dihystera*) was identified by Cobb in Hawaii (1893). Other genera such as *Rotylenchus* spp. and *Scutellonema* spp. are referred to as spiral nematodes and have been described from sugarcane in Rhodesia and Kenya (Prasad, 1972). Spiral nematodes do not cause serious damage to sugarcane. It is generally considered that spiral nematode damage is too low to economically merit specific control measures nor have resistant cultivars been developed.

Stubby-Root Nematodes: Several *Trichodorus* and *Paratrichodorus* species, which also cause stubby-root disease of corn and vegetable crops, are found on sugarcane wherever this crop is grown. Stubby-root nematodes have been identified in Hawaii, South Africa, Australia, the Dominican Republic, Puerto Rico, Cuba, Florida, Louisiana, and many other countries where sugarcane is produced. Although it is believed to cause severe damage to sugarcane there is little experimental evidence. Jensen et al. (1959) found *P. minor* and *P. porosus* to be associated with sugarcane decline in Hawaii. Martin and Birchfield (1955) reported the association of this nematode with sugarcane in Louisiana.

Christie (1959) reported difficulties in controlling species of stubby-root nematodes on corn and vegetables in Florida. These pests were easily killed by fumigant-type chemicals but re-established rapidly after 6 weeks and continued to build into large populations on suitable hosts. Limited field observations suggested that fallow or fallow and tillage may be effective against stubby-root nematodes but that flooding is not very effective. *Paratrichodorus minor* populations were effectively reduced in Louisiana sugarcane fields after nematicide treatments with organophosphates and carbamates. Yields were increased with nematicides where *P. minor* occurred with other plant parasitic nematodes.

Other nematodes: Many other nematode genera have been associated with sugarcane, but little is known about their biology and the damage they cause. *Rotylenchus* spp. have been reported on sugarcane roots from several parts of the world but, in general, fail to reproduce on plants in the Graminae family. *Rotylenchus reniformis* does not parasitize sugarcane in Louisiana, but it is a serious parasite of sugarcane in Puerto Rico (Roman, 1961). *Belonolaimus gracilus* produced

disease symptoms on sugarcane in greenhouse tests, but it is not widely distributed in sugarcane growing areas. *Radophilus similis* parasitizes sugarcane (Van Zwaluwenbury, 1932; Williams, 1959). Other nematode genera associated with sugarcane are: *Longidorus*, *Criconema*, *Hemicycliophora*, *Dolichodorus*, *Criconemella*, *Hemicriconemoides*, *Xiphinema* and various members of Dorylaimidae (Prasad, 1972). The economic importance of these nematodes on sugarcane is unknown.

Yield Losses

Sugarcane yield loss caused by nematode infestations are not well documented. It is generally believed that no single nematode species causes enough damage to merit chemical control. However, it is believed that nematode damage is caused by a complex of nematodes which transmit root diseases. It should be emphasized that the general lack of knowledge about nematode damage indicates that it is not a serious pest. The lack of research data is related to the difficulty in sampling or surveying sugarcane due to its long growth cycle. At this point, however, producers are not willing to invest in nematode control.

Pest Management

Current Chemical Usage

There is currently no specific nematode control program in any state using aldicarb or its alternatives. Carbofuran and ethoprop are used to some extent for wireworm and other soil borne pests, mostly in Florida. It is estimated that 47,000 acres of Florida sugarcane were treated with ethoprop in 1986. Aldicarb is thought to be more efficacious than other contact-type materials such as carbofuran or ethoprop. Fumigants containing 1,3-D provide excellent control when used properly. On sandy soils they would be as effective or offer improved control over aldicarb. However, aldicarb is the best nematicide on heavy soils or soils high in organic matter (Dunn, 1989).

Non-Chemical Management Alternatives

There are few nonchemical practices that provide effective control of nematodes. In Florida, flooding is used in certain circumstances to control wireworms on muck soils. However, soils must be flooded 6-months to 1-year to achieve nematode control (Dunn, 1989). The average flooding period in Florida is 1-2 months (Coale, 1989). Although flooding is not itself an expensive operation, it requires removal of land from sugarcane production for a longer period than producers are willing to accept. Flooding is not used in other states producing sugarcane.

There are no nematode resistant cultivars available to sugarcane producers (Nickle, 1984). Sugarcane is a crop that is generally grown for three to five years and harvested three to five times from one planting. The shortest period it is grown is 2 years (Hawaii). This long crop cycle makes it difficult to enter into comprehensive rotational programs. Furthermore, land suitable for the growth of sugarcane is in demand and low dollar returns from growing rotational crops are not attractive to growers. It is the general feeling of nematologists that rotation programs for the control of nematodes in sugarcane has not been popular and a great deal of research would be needed in order to establish an acceptable program. There are several reasons that little effort has been

put into the development of sugarcane rotations. Sugarcane is grown for 3 to 5 years and is harvested one-time per year. This long crop cycle makes it difficult to initiate rotation programs. In addition, land suitable for sugarcane production is in short supply and crops grown in the rotation are not as profitable.

Economic Impacts

Aldicarb is registered for use only in Louisiana and it has not been used there for 5 years (Graves, 1989). Ethoprop and carbofuran are sometimes used for the control of wireworms and perhaps other soil borne arthropods so it is possible that these materials could also control nematodes. Based on current usage of aldicarb, there would not be any changes in sugarcane yields or in net profits to producers.

Summary

A total of 822,000 acres of sugarcane is grown in Florida, Hawaii, Louisiana and Texas; Florida accounts for 50 percent of production. Aldicarb is not applied to any sugarcane acreage in the United States. The chemical alternatives to aldicarb are carbofuran and ethoprop; these are contact nematicides that are used primarily to control wireworms and other soil pests. Liquid fumigants such as 1,3-dichloropropene may also be used. Aldicarb is thought to be more efficacious than other contact-type chemicals such as carbofuran or ethoprop. Fumigants such as 1,3-D also provide excellent control when used properly. On sandy soils they would be as effective or offer improved control over aldicarb. However, when used on heavy soils or soils high in organic matter, aldicarb may provide the best control (Dunn, 1989).

Integrated pest management tactics are not used for nematode control to any significant degree. There are no known sugarcane cultivars resistant to nematodes. Rotation programs are not used due to high land cost and limited availability of desirable sugarcane land. Growers are also reluctant to use flooding or any other nonchemical control method that removes land from sugarcane production.

It is expected that there would be a small increase in sugarcane production costs if nematodes became a serious problem and aldicarb alternatives were used for control. However, the increased cost to consumers would be negligible.

Limitations of the Analysis

This benefits analysis was limited by: 1) a lack of sufficient research that addresses the true nematode situation in all sugarcane production areas, 2) a lack of knowledge regarding the efficacy of each nematicide on specific nematodes, 3) a lack of understanding of the role nematodes may play in vectoring diseases, particularly viruses, that may cause serious damage to sugarcane, and 4) a lack of individual grower input due to time and funding limitations.

Table 86. Number of farms, acreage, total production and value of sugarcane in the United States

State	Production use	# of Farms	Harvested acreage	Total production (1000 tons)	Yield per acre (tons)	Total value ($1000)
Florida	sugar	203*	414,000**	13,662**	33	**403,063
Hawaii	sugar	205*	88,000**	8,184**	93	**231,241
Louisiana	sugar	806*	287,000**	7,175**	25	**177,965
Texas	sugar	162*	33,000**	1,023**	31	**28,801
Florida	seed	64*	12,000*	399*	33.25	NA
Hawaii	seed	37*	NA	194*	NA	NA
Louisiana	seed	479*	15,576*	450*	28.89	NA
Alabama	syrup	4*	5*	4,481 lbs.*	0.45	NA
Florida	syrup	22*	110*	223,463 lbs.*	2.03	NA
Georgia	syrup	(Data withheld*)				
Louisiana	syrup	3*	3*	3,560 lbs.*	0.59	NA

Sources: * = 1982 Census of Agriculture, Bureau of Census.
** = 1988 USDA, NASS Summary of Crop Production & Values

Table 87. Aldicarb and alternative nematicides used on sugarcane

Material	Formulations*	Use restrictions	Use cycle	Target pests
Aldicarb	15G	use only in Louisiana	plant cane	nematodes
Carbofuran	10G, 15G	no use in Hawaii	plant cane/ stubble cane	root-knot, stunt nematodes
Ethoprop	10G,15G,20G,6EC		plant cane	lesion, root-knot, ring, stunt**, stubby, root nematodes
1,3-Dichloropropene	liquid***		preplant	nematodes
Telone C-17	liquid***		preplant	nematodes
Vorlex	liquid***		preplant	nematodes, damp off, root-rot & wilt fungi

* See individual rates under cost comparisons. Liquids use low rates for mineral soils and high rates for muck (peat) soils.
**Only the 20G formulation is labelled for control of stunt nematodes on sugarcane.
*** See per cent composition under cost comparisons.

Table 88. Cost of aldicarb and alternative nematicide used on sugarcane				
Material	Formulation	Rate/acre lbs/gal	Pounds ai	Cost per acre
Aldicarb	15G	10-20	1.5-3.0	$23.81-47.61
Carbofuran	10G	20-40	2.0-4.0	NA
Carbofuran	5G	13-26	2.0-4.0	$17.34-34.68
Ethoprop	10G	20-40	2.0-4.0	NA
Ethoprop	15G	13-26	2.0-4.0	NA
Ethoprop	20G	10-20	2.0-4.0	$12.50-25.00
Ethoprop	6EC	1.3-2.7 qt	2.0-4.0	$17.00-34.00
1,3-Dichloropropene	94%	4-12 gal.	41-109	$35.20-105.60
1,3-Dichloropropene Chloropicrin	74% 16%	5-14 gal. 5-14 gal.	40-107 9-24	$55.10-155.40
1,3-Dichloropropene MITH	40% 20%	7-25 gal. 7-25 gal.	24-86 12-43	$92.75-331.25

Note: Telone II weighs 10.1 lbs per gallon; Telone C-17 contains 7.82 lbs. AI of 1,3-dichloropropene and 1.79 lbs. AI chloropicrin per gallon; Vorlex weighs 8.6 lbs. per gallon; Vorlex is generally recommended at the broadcast rate.

Ornamental Crops

Aldicarb Use on Ornamentals

Karen L. Robb, Ronald D. Oetting, Donald E. Short, and Gordon Nielsen

Ornamental plant production is one of the fastest growing industries in U.S. agriculture. The ornamentals industry has grown at an average annual rate of 10 percent per year since 1986; in 1987 it accounted for 11 percent of all farm cash receipts (Johnson, 1989). The rapid growth of this industry has made an accurate economic analysis extremely difficult. As a result, the impact of the ornamental plant industry on local economics has not been fully recognized in many areas. Ornamental plant production can be classified into several categories, including floriculture, nursery crops, and Christmas trees. Floriculture can be further categorized as cut flowers, bedding plants, and potted plant production. Each production system has its individual characteristics and practices. Christmas tree production and landscape maintenance systems will not be discussed since aldicarb is not utilized in these systems. There were 8,901 growers of commercial floricultural crops recorded in 1988. The total covered growing area, including glass, plastic and shade houses, was 16,676 to 24,616 acres of open land devoted to the production of floricultural crops (Anon., 1988; Johnson, 1989).

Bedding plants refer to any annual, biennial or perennial plant, usually seed propagated and grown outdoors during the warmer months. In some areas, plants are moved outside the greenhouse after transplanting. In other areas, most crops are grown entirely in the greenhouse until they are sold to retailers. Over 50 plants are grown, exclusive of vegetable crops, as bedding plants. More than 5,140 acres were devoted to bedding plant production in 1988 (Table 89) with a wholesale value of $592.5 million (Anon., 1988). Potted plant production includes foliage plants as well as flowering plants. These plants are usually propagated in greenhouses by either seeds, cuttings, air-layers or division. After propagation, the plants may be grown either outdoors or under protection. Potted plant production utilized more than 8,585 acres in 1989 (Table 90) with a reported wholesale value of $917.8 million (Anon., 1988).

Cut flower production includes production of cut greens used for floral arrangements. Cut flowers can be produced in open areas or under the protection of greenhouse structures. Floral crops may be produced from seed, bulbs, or cuttings and may be annual, biennial or perennial plants. A crop may be in the ground for as short as 9 weeks or as long as several years. Although cut flowers produced in greenhouses are usually more valuable than field grown flowers on a per area basis, the majority of flowers are produced without protection (Table 91).

Floriculture is a high input/high value production system. Values of cut carnations, chrysanthemums and roses averaged $2.98/square foot and for all cut flowers averaged $0.65 per square foot in 1988. The value of potted plants, cut greens, and flowering potted plant production averaged $2.57, $0.40, and $2.48 per square foot in 1988, respectively (Anon., 1988). Personal expenditures for cut flowers and potted plants was predicted to be $46.76 per capita in 1989 (Johnson, 1989). The nursery industry is represented by growers of woody ornamental plants (shrubs, shade trees), fruiting plants, and forest trees. The value of an acre of nursery varies from $20,000 to $40,000 and requires 2 to 4 years to reach marketable size. There were 1,657 acres of nursery under protective cover and 205,382 open acres of nursery (Table 92) (Census of Agriculture, 1982).

Registration Summary

Aldicarb is registered for use on greenhouse grown chrysanthemums, orchids, Easter lilies, poinsettias, gerberas, carnations, roses and snapdragons, as well as field and nursery grown roses, dahlias, lilies, bulbs, birch and holly. In addition, there are numerous states that have Special Local Need or 24(c) registration for aldicarb use on ornamental plants and nursery stock. The labeled rate of application varies from 5 to 10 pounds active ingredient (lb ai) per acre depending upon the target pest.

Aldicarb occupies an unique position in terms of ornamental plant pest control due to its systemic activity and long-term efficacy. It is applied to the media in pots or on soil and the active ingredient is absorbed by roots and translocated throughout the plant. Aldicarb has residual activity and provides control of some pests for up to 6 weeks. Therefore, repeat applications are not required for 4 to 8 weeks. The final application must not be within 4 weeks of marketing. In most crop systems only one or two applications will be made on the crop because of the short duration of most crops. Many producers of ornamental plants apply aldicarb shortly after planting as a preventative measure to insure a pest-free start for high-value aesthetic crops. This is particularly true for woolly whitefly control on poinsettias.

Aldicarb is registered for use on many of the major pests of ornamental crops. It is registered on spider mites, including the two-spotted spider mite (*Tetranychus urticae* Koch), which is one of the most frequently occurring and difficult to control pests of ornamentals. The label includes control of aphids, leafminers, thrips, whiteflies, and mealybugs, important ornamental pests that have become more difficult to control over the last 10 to 20 years.

Pest Management

Current Chemical Usage

The responses to the 1988-89 NAPIAP pesticide use questionnaire were used to estimate aldicarb usage by the U.S. ornamental plant production industry. Responses were received from 29 states and Puerto Rico. The total annual use of aldicarb by the ornamental plant industry was approximately 162,824 lb ai. Aldicarb is most frequently used on potted plants, with almost 40 percent of production acreage being treated with 32,380 lb ai of aldicarb per year. More than 25 percent of total cut flower production is treated with aldicarb, accounting for 39,728 lb ai of aldicarb usage per season. Aldicarb use on about 20 percent of the acreage of bedding plant production accounted for 5,532 lb ai Although less than 8 percent of the total nursery acreage was treated with aldicarb, this represented the largest amount of chemical applied (85,185 lb ai). The average price of aldicarb was $38.50 per lb ai, formulated on granules of 10 percent (w/w) active ingredient. The cost for an application of aldicarb averaged $20.00 per acre to distribute the granules into pots or on rows.

<u>Bedding Plants:</u> Only five states (California, Florida, New Hampshire, New York and Tennessee) reported any use of aldicarb on bedding plants (Tables 93 and 94). Aphids, whiteflies and mites were the most common target pests of 1-2 applications of aldicarb per season (Tables 95 and 96). Seven insecticide formulations were listed as possible alternatives to aldicarb. The pesticide alternatives suggested by individual states are listed in Table 97.

Potted Plants: More states reported use of aldicarb on potted plants than any other ornamental commodity (Tables 98, 99 and 100). Eighteen of the 29 states reported some usage of aldicarb on plants grown in pots under greenhouse and field conditions. Whiteflies, aphids and thrips were among the commonly listed target pests (Table 101). One to four applications of 5-10 lb ai/acre were reported for use on potted plants. Fourteen insecticide formulations were reported as possible alternatives to aldicarb. Pesticide alternatives suggested by individual states are listed in Table 102.

Cut Flowers and Greens: Florida, New York, Oregon, and California reported the greatest usage of aldicarb in cut flowers (Tables 103 and 104). One to two applications were recommended for control of the target pests (Tables 105, 106). The nine suggested pesticide formulation alternatives are listed in Table 107.

Nursery Crops: The percent of nursery acreage treated with aldicarb was low in all states except Florida and New York (Table 108). However, the high acreage and/or volume of nursery production resulted in this being a major use for aldicarb with 85,185 lb ai being applied to nursery crops (Tables 109 and 110). The target pests for aldicarb on nursery crops are listed in Table 111. Alternative pesticides for pest control if aldicarb were no longer available are listed in Table 112.

Chemical Alternatives for Pest Management

The alternative controls, by crop, are presented in Tables 97, 102, 107 and 112. Aldicarb is unique since it is applied in a granular formulation to the substrate within which a plant is growing, and it has systemic activity on a large number of pests. There are only two alternative chemicals that have similar use patterns. Oxamyl 10G has a similar application pattern and is registered for a similar pest complex. Disulfoton is also a granular insecticide but it is limited to outdoor use. In commercial production of ornamentals disulfoton is used on field flowers. The disulfoton label is similar to aldicarb in the range of pests on the label. It also has similar duration of residual activity. One alternative, sulfotepp, is a space fumigant. The only location where sulfotepp can be used is in greenhouse production. It is used as a quick knockdown material but does not have any residual activity. Sulfotepp is used primarily for whitefly control.

All other reported alternative insecticides are applied as full coverage foliar sprays. A few can be used as drench treatments. Oxamyl 2L and dimethoate are systemics and have some residual activity but are usually applied as foliar sprays and not as drench treatments. The labeled pests are similar for aldicarb, oxamyl and dimethoate but the latter two materials require more applications. The dimethoate label does not include greenhouse usage and is limited to field grown ornamentals. The remaining alternatives have short residuals and require repeat applications. The target pests for these compounds are not as extensive as for aldicarb. Use of these alternative chemicals requires that several different materials be applied at short intervals to obtain the same control, resulting in a need for more equipment and labor.

Non-Chemical Management Alternatives

Research on nonchemical alternatives to aldicarb for control of two-spotted spider mites, whiteflies, aphids, and thrips is underway in several states. However, none of these alternatives have been developed sufficiently for use by producers. Researchers are evaluating the potential for use of predators, parasitoids, and entomopathogens for control of pests of ornamental crops. Cultural practices, such as sanitation, can be used to reduce the pest impact on the crop but will

not eliminate the need for chemicals. Improved cultural practices would be adopted by many producers if aldicarb were no longer for available pest control.

Economic Impacts

The economic impacts associated with the loss of aldicarb for use on ornamental plants is difficult to assess. Table 113 lists the different alternative insecticides reported by state specialists and the cost of using aldicarb alternatives. In some situations a rotation of chemicals is used for a single pest species. The amount of active ingredient needed for pest control varies among the alternatives. For example, abamectin could replace aldicarb for the control of mites and leafminers. In programs where abamectin is used for two-spotted mite control, the rate of application is 0.01 lb ai/acre and one or two applications would be made in 5 weeks. Using the cost figures from Table 113 the cost of mite control with abamectin could be as low as $125.75 compared to the $212.50 value for aldicarb. However, the use of abamectin to replace aldicarb for leafminer control would require applications every 5 to 7 days at a rate 0.02 lb ai/acre. The cost of abamectin application would then be $880.25 to $1,760.50 to replace aldicarb for five weeks duration.

The replacement of aldicarb with alternative chemicals would require an increase in the number of applications and the number of different insecticides utilized. The cost for treating 100 acres of ornamentals with alternative insecticides would only increase slightly from $21,250 to $21,972 (Table 114). Therefore the economic impact as a result of the cost of chemicals and application would not be significant. However, this does not include the cost of special spray equipment, equipment maintenance, and lost employee time that would be required with most of the alternatives. There is not any data available for these costs but they would be significant.

Summary and Recommendations

The economic impact caused by the loss of aldicarb on ornamentals production would not be significant. However, equipment and labor costs would increase. There is no single aldicarb alternative that can replace aldicarb. Economic comparisons do not adequately reflect the impact of the loss of aldicarb on ornamentals production. If aldicarb were not available for pest control, there would be a large increase in the number of insecticides used and in the number of applications required. This would increase the risk of worker exposure and in the potential for damage to the environment.

Table 89. Production area and sales of bedding plants*

Production site	Area (acres)	Total sales ($)
Greenhouse	1,542	
Open	3,598	
Total	5,140	592,495,000

*Source: 1988 Floriculture Crop Survey, National Acad. Statistical Survey

Table 90. Production area and sales of potted plants*

Production site	Area (acres)	Total sales ($)
Greenhouse	2,146	
Open	6,439	
Total	8,585	917,852,000

*Source: 1988 Floriculture Crop Survey, National Acad. Statistical Survey

Table 91. Production area and sales of cut greens and flowers*

Production site	Area (acres)	Total sales (x $1,000)
Greenhouse	3,520	315,704
Open	19,946	209,190
Total	23,466	524,894

*Source: 1988 Floriculture Crop Survey, National Acad. Statistical Survey

Table 92. Production area and sales of nursery crops*

Production site	Area (acres)	Total sales ($)
Greenhouse	1,657	
Open	205,382	
Total	207,039	1,155,422,000

*Source: 1982 Census of Agriculture

Table 93. Percent of bedding plants treated with aldicarb		
State	% Greenhouse production treated	% Open area treated
California	<5.0	0.0
Florida	50.0	50.0
Idaho	0.0	5.0
Illinois	0.0	0.0
Louisiana	0.0	0.0
New Hampshire	25.0	0.0
New York	48.0	0.0
Tennessee	(*)	(*)

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.
* Limited use and figures not available

Table 94. Estimated bedding plant acreage treated with aldicarb

State	% Aldicarb treated		Acreage production		Acreage treated	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
California	<5.0	0.0	254	1,397	12.7	0
Florida	50.0	50.0	438	785	219.0	393
Idaho	<5.0	---	14	0	0.7	0
New Hampshire	25.0	0.0	17	11	4.3	0
New York	48.0	0.0	234	90	112.0	0
Total	36.5	17.2	957	2,283	349.7	393

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 95. Estimated amounts of aldicarb applied to bedding plants						
State	Rate (lb ai)		Average number applications/seasons		Amounts applied (lbs/season)	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
California	5.0	0.0	1	0	63.5	0.0
Florida	5.0	5.0	1-2	1-2	2,190.0	7,850.0
Idaho	>5.0	--	1	--	3.5	0.0
New Hampshire	5.0	0.0	1-2	0	43.0	0.0
New York	5.0	0.0	1-2	0	1,123.0	0.0
Subtotal					3,434.0	7,850.0
Total						11,273.0

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 96. Target pests of aldicarb applications to bedding plants		
State	Total acres treated with aldicarb	Target pests
California	12.7	Aphids,leafminers,whiteflies, mites
Florida	612.0	Aphids,leafhoppers,leafminers, mites,nematodes,thrips,whiteflies
Idaho	0.7	Aphids,whiteflies,mites
New Hampshire	4.3	Aphids,whiteflies,mites
New York	112.0	Aphids,whiteflies,mites

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 97. Pesticide alternatives to use of aldicarb on bedding plants					
Alternative	State	% Aldicarb plants to be treated	Rates (lb ai/acre)	Avg #1 season	Est. % change in quality
Acephate	California	40	0.5	1-2	0
Chlorpyrifos	California	40	0.5	1-2	0
Diazinon	Florida	10-15	0.5	1-2	0
Dimethoate	Florida	20-30	1.0	1-2	0
Methomyl	California	20	0.9	1-2	0
	Florida	20-30	0.9	1-2	0
Oxamyl	Florida	20-30	1.0	1-2	0
Oxamyl 10G	New Hampshire	100	10.0	1-2	0
	New York	100	10.0	1-2	10

Source: Survey of State pesticide coordinators and/or extension specialists in 1988-89.

Table 98. Percent of potted plants treated with aldicarb in states when it is used for this purpose		
State	% Greenhouse production treated	% Open area treated
Alabama	75	0
Arkansas	5	0
California	30	0
Florida	50	50
Georgia	65	0
Hawaii	25	0
Idaho	0	5
Mississippi	<1	0
New Hampshire	10	0
New Jersey	50	15
New York	35	0
Ohio	<5	0
Oregon	35	0
Rhode Island	75	0
South Carolina	35	0
Tennessee	(*)	(*)
Vermont	35	0
Virginia	80	80

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.
* limited use and figures are not available

Table 99. Estimated potted plant acreage treated with aldicarb

State	% Aldicarb treated		Acreage in production		Acreage treated	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Alabama	75	0	115	--	86.3	0.0
Arkansas	5	0	17	--	0.9	0.0
California	30	0	1232	--	369.6	0.0
Florida	50	50	385	4491	192.5	2245.5
Georgia	65	0	115	--	74.8	0.0
Hawaii	25	0	193	--	48.3	0.0
Mississippi	<1	<1	218	54	2.2	0.5
New Hampshire	10	0	217	54	21.7	0.0
New Jersey	50	15	112	14	56.0	2.1
New York	35	0	215	--	75.3	0.0
Ohio	<5	0	277	--	13.9	0.0
Oregon	35	0	83	--	29.1	0.0
Rhode Island	75	0	12	--	9.0	0.0
South Carolina	35	0	--	--	--	--
Vermont	35	0	3	--	1.1	0.0
Virginia	80	0	42	--	33.6	0.0
Subtotals					1,014.3	2,248.1
Total						3,248.1

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 100. Estimated amounts of aldicarb applied to potted plants

State	Rate (lb ai)		Average number applications/season)		Amounts applied (lbs ai/season)	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Alabama	10.0	--	4	--	3452.0	0.0
Arkansas	10.0	--	1.5	--	13.5	0.0
California	10.0	0.0	1	0	3696.0	0.0
Florida	5.0	5.0	1.5	1.5	1443.8	16841.3
Georgia	10.0	--	3	--	2244.0	0.0
Hawaii	10.0	--	2	--	966.0	0.0
Mississippi	--	--	--	--	---	0.0
New Hampshire	10.0	0.0	2	0	44.0	0.0
New Jersey	7.5	7.5	4	2	1680.0	31.5
New York	10.0	0.0	1.5	0	1129.5	0.0
Ohio	5.0	--	2	--	139.0	0.0
Oregon	10.0	--	1	--	291.0	0.0
Rhode Island	10.0	--	1.5	--	135.0	0.0
Vermont	10.0	--	2	--	22.0	0.0
Virginia	7.5	--	1	--	252.0	0.0
Subtotals					15,507.3	16,872.8
Totals						32,380.1

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 101. Target pests of aldicarb applications to potted plants

State	Total acres treated with aldicarb	Target pests
Alabama	86.3	Whiteflies, scales, mites
Arkansas	0.9	Whiteflies, mites
California	369.6	Whiteflies, aphids, leafminers, mites
Florida	2438.0	Aphids, leafhoppers,leafminers, mites, nematodes,thrips, whiteflies
Georgia	74.8	Whiteflies, aphids, mealybugs, thrips
Hawaii	48.3	Whiteflies, aphids, thrips, mites
New Hampshire	21.7	Whiteflies, aphids, mites
New Jersey	58.2	Whiteflies, aphids, thrips, mealybugs, mites
New York	75.3	Aphids, whiteflies, mites
Ohio	13.9	Whiteflies, thrips
Oregon	29.1	Whiteflies, aphids, thrips, mites
Rhode Island	9.0	All pests
Vermont	1.1	Whiteflies, aphids, thrips
Virginia	33.6	Whiteflies

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 102. Pesticide alternatives to use of aldicarb on potted plants					
Alternative	State	% Aldicarb plants to be treated	Rates (lb ai/acre)	Avg #1 season	Est. change in quality
Abamectin	California	25	0.01	2-4	10
Acephate	Arkansas	30			
	California	20	0.5	1-2	20
	Mississippi	25	0.5		0
	Vermont				
Bifenthrin	Mississippi	25	0.1		0
	Vermont				
Chlorpyrifos	California	25	0.5	2-4	10
Diazinon	Florida	10-15	0.5	1-2	0
Dichlorvos	Arkansas	30			
Dimethoate	Florida	20-30	1.0	1-2	0
Disulfoton	Alabama	25			20
Fluvalinate	Mississippi	25	0.1		0
	Vermont				
Methomyl	California	20	0.9	2-4	10
	Florida	20-30	0.9	1-2	0
Oxamyl	Alabama	75			10
	Florida	20-30	0.5	1-2	0
	Georgia	75	0.5	2-4	50
	New Hampshire	75	0.5	1-2	0
	Mississippi	25	0.5		
Oxamyl 10G	Ohio	100	10.0		
	Rhode Island	100	5.0	1-2	10
Plantfume 103	California	10		2-4	10
Resmethrin	Arkansas	30			
	Vermont				

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 103. Percent of cut flowers and greens treated with aldicarb in states where it is used for this purpose.		
State	% Greenhouse production treated	% Open area treated
Arkansas	50	0
California	33	15
Florida	50	50
Idaho	0	5
New York	75	15
Oregon	0	15
Rhode Island	5	0
South Carolina	5	0
Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.		

Table 104. Estimated cut flower and green acreage treated with aldicarb						
State	% Aldicarb treated		Acreage in production		Acreage treated	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Arkansas	50	0	1.6	--	0.8	0
California	33	15	1532.0	5723.0	506.0	58
Florida	50	50	324.0	8216.0	162.0	4108
New York	75	0	62.0	40.0	46.5	0
Oregon	0	15	39.0	739.0	0.0	111
Rhode Island	5	0	1.4	4.0	0.1	0
South Carolina	5	0	2.0	--	0.1	0
Subtotals				715.5	4277.5	
Total					4993.0	
Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.						

Table 105. Estimated amounts of aldicarb applied to cut flowers and greens						
State	Rate (lb ai)		Average number applications/season		Amounts applied (lb ai/season)	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Arkansas	10	--	2	--	16.0	0
California	10	10	1	1	5060.0	585.0
Florida	5	5	1.5	1.5	1215.0	30,810.0
New York	10	0	2	0	930.0	0.0
Oregon	10	--	1	--	0	1110.0
Rhode Island	10	--	1.5	--	1.5	0.0
South Carolina	10	--	1	--	0.1	0.0
Subtotal					7,222.6	32,505.0
Total						39,727.6

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 106. Target pests of aldicarb applications to cut flowers and greens		
State	Total acres treated with aldicarb	Test pests
Arkansas	0.8	Mites
California	564.5	Whiteflies, aphids, leafminers
Florida	4270.0	Aphids, leafhoppers, leafminers, mites, nematodes, thrips, whiteflies
New York	46.5	Aphids, whiteflies, mites
Oregon	29.1	Aphids, nematodes
Rhode Island	9.0	All pests

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 107. Pesticide alternatives to the use of aldicarb on cut flowers and greens					
Alternative	State	% Aldicarb plants to be treated	Rates (lb ai/acre)	Avg #1 season	Est. change in quality
Abamectin	California	40	0.01	2-4	0
Acephate	Arkansas California	20	0.25	1-2	0
Chlorpyrifos	California	15	0.5	2-4	0
Diazinon	Florida	10-15	0.5	1-3	0
Dienchlor	Arkansas				
Dimethoate	Florida	20-30	0.4	1-3	0
Methomyl	California Florida	15 20-30	0.9 0.9	2-4 1-2	0 0
Oxamyl	California Florida	10 20-30	0.5 0.5	2-4 1-2	0 0
Oxamyl 10G	New York	100	10.0	4-8	>50

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 108. Percent of nursery crops treated with aldicarb in states where it is used for this purpose.		
State	% Greenhouse production treated	% Open area treated
Alabama	5	5
Arkansas	0	0
California	<5	<5
Florida	0	50
Georgia	5	5
Hawaii	5	5
Idaho	0	5
New York	10	25
Oregon	0	15

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 109. Estimated nursery acreage treated with aldicarb

State	% Aldicarb treated		Acreage in production		% Acreage treated	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Arkansas	5	5	69	4365	3.5	218.0
California	<5	<5	361	25,748	18.0	1,287.4
Florida	0	50	293	17,500	0.0	8,750.0
Georgia	5	5	16	6,000	0.8	300.0
Hawaii	5	5	29	292	1.4	14.6
New York	10	35	87	17,625	8.7	4,406.3
Subtotals					31.6	14,976.3
Total						15,007.9

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 110. Estimated amounts of aldicarb applied to nursery crops

State	Rate (lb ai)		Average number applications/season		Amounts applied (lbs/Season)	
	Greenhouse	Open	Greenhouse	Open	Greenhouse	Open
Arkansas	10	10	1	1	35	2,180
California	10	10	1	1	180	12,874
Florida	0	5	0	1.5	0	65,625
Georgia	10	10	1	1	8	3,000
Hawaii	10	10	1	1	14	146
New York	5	0	1-2	0	1,123	0
Subtotals					1,360	83,825
Total						85,185

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 111. Target pests of aldicarb applications to nursery crops		
State	Total acres treated with aldicarb	Target pests
Alabama	221.8	Mites, scales, whiteflies
California	1,305.4	Aphids, leafminers, whiteflies, scales, nematodes
Florida	8,750.0	Scales, leafminers, mites, whiteflies, nematodes, thrips
Georgia	300.0	Aphids, mites, thrips, scales
Hawaii	16.0	Aphids, thrips, mites, scales, whiteflies
New York	4,415.0	Aphids, leafminers, nematodes, soil insects

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 112. Pesticide alternatives to use for aldicarb on nursery crops					
Alternative	State	% Aldicarb Plants to be Treated	Rates (lb ai/acre)	Avg #1 season	Est. change in quality
Acephate	California	20	0.5	1-2	0
	Florida	20-30	1.0	1-3	0
Chlorpyrifos	California	20	0.5	1-2	0
D-D Mix	New York			1	0
Demeton	New York			1	0
Diazinon	California	20	0.5	1-2	0
	Florida	10-15	0.5	1-3	0
Dimethoate	Alabama	33	0.5	1-2	
	Florida	20-30	0.4	1-3	0
	New York			2	0
Disulfoton	Alabama	33	10.0	1	
	California	20	10.0	1	0
	Georgia	80	10.0		0
Oxamyl 10G	Alabama	33	10.0	1	
	California	20	10.0	1	0
	Florida	20-30	5.0	1-3	0
	Georgia	20	10.0		0

Source: Survey of state pesticide coordinators and/or extension specialists in 1988-89.

Table 113. Insecticide cost comparisons for a five week period. The usage pattern would vary with different pests and repeated use of many materials would not be possible because of label restrictions

Alternatives	Cost[a] (ai/acre)	Rate[a] (lb ai/acre)	Cost per acre	No.[b] application	Cost of[c] application	Total cost
aldicarb 10G	$ 38.50	5.0	$192.50	1	$ 20	$212.50
abamectin .15E	3525.00	0.01	105.75	2	40	251.50
acephate 75S	8.73	0.5	4.37	5	100	121.83
bifenthrin 10W	550.00	0.1	55.00	5	100	375.00
chlorpyrifos 2E	7.45	0.5	3.73	5	100	118.63
diazinon 2E	6.00	0.5	3.00	5	100	115.00
diazinon enc.2F	25.00	0.5	12.50	5	100	152.50
dimethoate 2E[d]	7.55	1.0	7.55	3	60	82.65
disulfoton 15G[d]	10.00	5.0[e]	50.00	1	20	70.00
fluvalinate 2E	148.00	0.1	14.80	5	100	172.50
methomyl 1.8L	14.21	0.5	7.11	5	100	135.55
oxamyl 2L	23.45	0.5	11.73	3	60	95.19
oxamyl 10G	38.13	5.0	190.63	2	40	421.26
resmethrin 2E	86.58	0.25	21.56	5+	100+	207.81
SulfoTepp Fum[f]	118.05	-	354.14	5+	-	1,770.00

a Cost of materials and rates based upon labels, manufacture, retail companies, and survey responses. Rates are expressed assuming 100 gallons of finish spray per acre.
b Number of applications is for cost comparisons, label restrictions may limit the number of repeat applications and there would be more phytotoxicity resulting from repeat application of some materials.
c All cost of application is figured at $20/application and no accounting is made of cost of equipment, maintenance, etc. because data are not available.
d Usage is limited to field situations.
e Applied to field flowers at rate of 10.7 oz formulation/150 to 300 ft of row.
f This compound is formulated as an fumigant and rate is figured on the basis of 2,000 sq ft per canister to get a per acre rate.

Table 114. Cost of replacing aldicarb with alternative insecticides for the control of pest groups. Comparison based only on the estimated cost of application and chemical

Pest Group	Insecticide	Number of applications	Percent replacement	Cost based upon percent of 100 acres	Total x % aldicarb usage
Mites (10 percent of aldicarb usage)	abamectin	1-2	50	$9,431.25	
	bifenthrin	1-2	25	2,812.50	
	fluvalinate	1-2	25	1,305.00	
	Total for 100 acres			13,548.75	$ 1,354.88
Aphids, leafhoppers, mealybugs, and whiteflies (70 percent of usage)	abamectin	6	5	$3,722.50	
	acephate	1-2	10	365.55	
	bifenthrin	1-2	10	1,125.00	
	chlorpyrifos	1-2	10	355.95	
	diazinon 2E	1-2	5	172.50	
	diazinon 2F	1-2	10	487.50	
	dimethoate	1-2	5	206.63	
	disulfoton	1-2	5	375.00	
	fluvalinate	1-2	10	522.00	
	methomyl	1-2	5	203.33	
	oxamyl 2L	1-2	5	237.98	
	oxamyl 10G	2	10	4,212.60	
	resmethrin	1-2	5	211.70	
	sulfotepp	1-2	5	2,656.05	
	Total for 100 acres			14,854.29	10,398.00
Thrips (10 percent of aldicarb usage)	abamectin	6	40	$29,780.00	
	acephate	1-2	10	365.55	
	chlorpyrifos	1-2	15	533.93	
	dimethoate	1-2	5	206.63	
	methomyl	3	20	1,626,64	
	oxamyl 10G	2	10	4,212.60	
	Total for 100 acres			36,725.35	3,672.54
Leafminer (10 percent of aldicarb usage)	abamectin	6	85	$64,132.50	
	chlorpyrifos	4	10	949.20	
	disulfoton	1-2	5	375.00	6,546.67
	Total for 100 acres			65,456.70	
	Total based on aldicarb replacement				$21,972.09
	Total for 100 acres of aldicarb				21,250.00
	Total estimated difference for alternative				-722.09

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